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Foundations of Nutrition



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Foundations of Nutrition

5TH EDITION

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Preface to the Fifth Edition

Those who have followed the science of nutrition during the past twelve years, since the fourth edition of this text was published, are well aware of the rapid progress which has been made during this span of years. Our many former students and the friends who have used this fundamental text over the years have urged the preparation of a fifth edition.

In the preparation of the first edition Mrs. Rose had in mind those who desired to "live more intelligently" and her aim was "to present within a small space some of the fundamental principles of human nutrition in terms which call for no highly specialized training in those natural sciences upon which the science of nutrition rests." The same purpose motivated her writing of the second and third editions of this text.

In the fourth edition and in this, the fifth, our objective has been the same. The interim between these editions has meant the accumulation of so much new material that its presentation and interpretation have necessitated the reorganization and rewriting of a large portion of the book. The newer knowledge of the metabolism and requirements of energy and protein; the recognition of new functions of mineral elements and vitamins; the discovery of heretofore unrecognized trace elements and vitamins and their role in human nutrition; the extension of our knowledge concerning the contributions made by foods as sources of amino acids, mineral elements, and vitamins; the many complex interrelations of the essential nutrients in metabolic processes which have been established; the diversity of ways in which foods supplement each other; the vast amount of information which has accumulated regarding the food habits of population groups in many parts of the world; and many other advances have made this reorganization and rewriting obligatory.

The tables of food values found in the Appendix are completely

new and have been planned to give the beginning student information about foods in addition to that presented in the previous edition. Several new tables have been developed to assist the beginning student in the practical application of the Recommended Daily Dietary Allowances suggested by the Food and Nutrition Board of the National Research Council.

We shall appreciate very much being informed of any errors or discrepancies discovered in using this text so that they can be corrected in a new printing.

We wish to express our sincere gratitude to Dr. Orrea F. Pye, Associate Professor of Nutrition at Teachers College, Columbia University, for her painstaking care in reading the manuscript and for her many helpful suggestions. To Dr. Ella McCollum Vahlteich for her invaluable assistance in the compilation of the tables of food values and the calculation of the dietaries, a service which she rendered in previous editions, we gratefully acknowledge our indebtedness. We also wish to express our appreciation to Edna R. Sostman, Assistant Professor of Home Economics, Douglass College of Rutgers University, State University of New Jersey, for her valuable assistance in connection with the assembling of the manuscript. To the many former students who have made helpful suggestions and the many individuals and organizations who have so generously contributed illustrations for this edition, we are deeply grateful.

C. M. T. and G. MacL.

New York City
March, 1956

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Historical Introduction

Section 1. SOME LANDMARKS IN THE DEVELOPMENT OF THE SCIENCE OF NUTRITION

The idea that there is a close connection between man's diet and his well-being is no innovation of the twentieth century. In an ancient chronicle we may read: "In the third year of the reign of Jehoiakim, king of Judah (607 B.C.), came Nebuchadnezzar, king of Babylon, unto Jerusalem, and besieged it." When the city fell into his hands, the king ordered that certain noble youths, "well-favored and skilful in all wisdom," be selected for training as courtiers. They were to have a special education and a daily portion of the king's meat, and of the wine which he drank. Living a carefully prescribed life, at the end of three years they would presumably be fit to stand before the great monarch. One of these youths "with knowledge and skill in all learning and wisdom" objected to the dietary part of the program and purposed in his heart that he would not eat the king's meat nor drink his wine; but the prince of the eunuchs, who had him in charge, protested, saying, "I fear my lord the king." The young man countered with a reasonable proposal: "Prove thy servants, I beseech thee, ten days; and let them give us pulse to eat and water to drink. Then let our countenances be looked upon before thee, and the countenance of the youths that eat of the king's meat." This seemed a fair bargain and so the nutrition experiment was undertaken, with the result that at the end of the ten days "their countenances appeared fairer and fatter in flesh than all the children which did eat the portion of the king's meat. So the steward took away their meat and the wine which they should drink and gave them pulse"; and when at the end of their probationary period the king examined them

they passed with a score ten times better than all the magicians and enchanters in his realm.¹

What Becomes of Food Eaten?

From that time to this, man has given much thought to the problem of where food goes when it is eaten and what it does to the one who eats it. But for many centuries the answers to such questions were philosophical rather than scientific. The greatest philosopher among the ancients with regard to food was Hippocrates, the famous

priest of Aesculapius officiating in the celebrated Health Temple of Cos in Greece in the day of Socrates and Plato, who by his wisdom and skill earned the title of Father of Medicine. The historian Strabo says that he was trained in dietetics, and some of his aphorisms have a modern sound, for example: "Growing bodies have the most heat; they therefore require the most food, for otherwise their bodies are wasted. In old persons the heat is feeble and therefore they require little fuel, as it were, to the flame for it would be extinguished by much." (Aphorism 14.)² But Hippocrates and his successors for two thousand years accounted for the disappearance of food as "insensible perspiration" and "heat" without any real understanding of what either term meant.

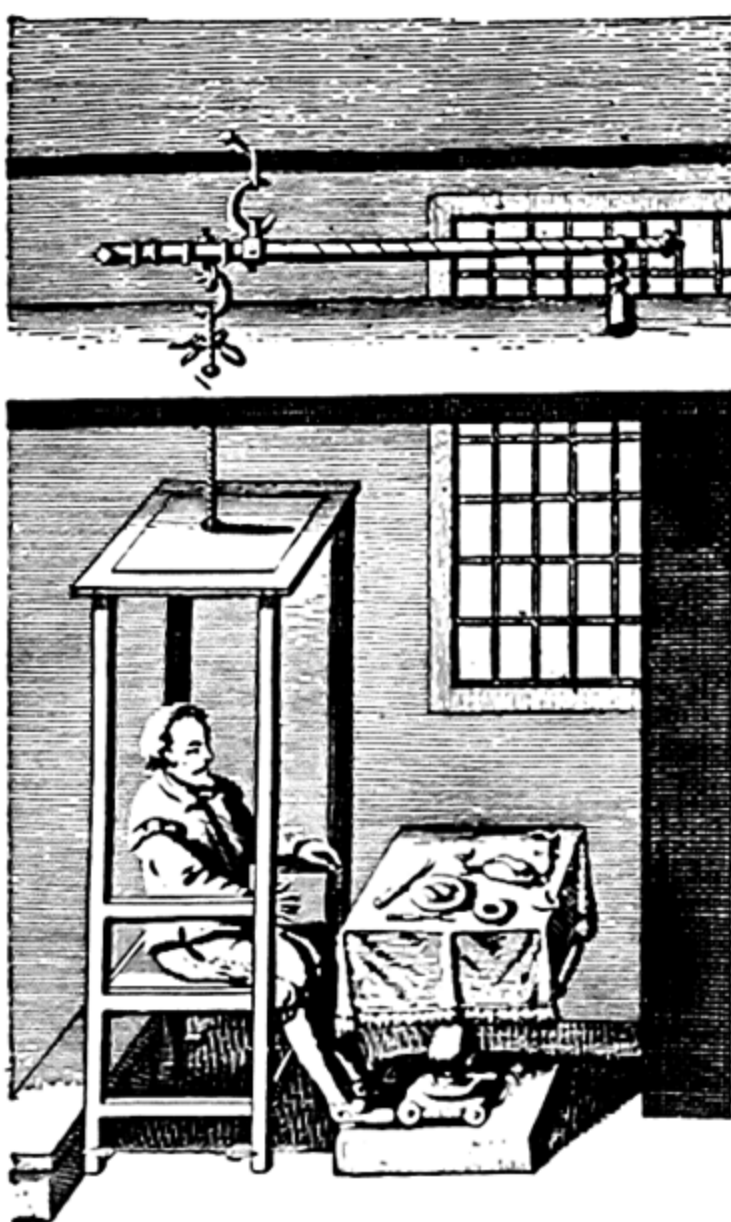


Fig. 1. Sanctorius on the Steelyard Which He Devised to Weigh Himself before and after Meals

In 1614 A.D. a university professor with a practical turn of mind devised a chair connected with a steelyard to weigh himself before and after meals, so that he might find out the amount of this "insensible perspiration," for he said: "He only who knows how much and when the body does more or less insensibly perspire will be able to discern

¹ Daniel I:1-15.

² Adams, Francis. *Genuine Works of Hippocrates*, page 197. William Wood and Co. (1891).

Historical Introduction

when or what is to be added or taken away, either for the recovery or the preservation of health." (Aphorism 3.)³ Even Sanctorius' painstaking efforts did not solve the mystery because in his day there was no science of chemistry. Not until about half a century later were experiments carried out which marked the beginning of chemistry as an exact science.

Air Is Essential for Life

In 1627 the Honorable Robert Boyle was born, seventh son of "the great Earl of Corke," destined to receive the best education of his day in England and on the continent and to become known to every student of chemistry or physics as a result of his studies on the "weight and spring of the air." In the course of his extensive investigations of the properties of the air, he conducted a large number of "pneumatical experiments about respiration." He put into the receiver of his "pneumatical engine" all sorts of small animals—"a kitling newly kittened," "a duckling that was yet callow," "a large and lusty frog"—to find out "whether there reside in the heart of animals such a fine and kindled, but mild substance, as they call a Vital Flame, to whose preservation, as to that of other flames, the Air (especially as is taken in and expelled again by respiration) is necessary." And Boyle found that it was necessary⁴ by placing a young mouse in a cylinder that was covered tightly with a thin rubber cap and putting this into a larger glass vessel out of which he could pump the air and observe the effect of this upon the animal. As the air was gradually withdrawn from the outer vessel the rubber cap on the inner vessel expanded. The mouse showed the effect of the resulting rarefaction of the air in the inner vessel by becoming very restless and leaping about as though trying to escape. Thereupon air was readmitted to the outer vessel, the rubber cap contracted to its original size, and the mouse quieted down. So this ardent chemist demonstrated to his full satisfaction the dependence of animals upon the air they breathe for life.

Still more significant respiration experiments were made by a young chemist named John Mayow, who came under the influence of Boyle and in 1668, at the age of twenty-eight, published a "Treatise

³ Lusk, Graham. *The Elements of the Science of Nutrition*, 4th edition, page 18. W. B. Saunders Co. (1928).

⁴ *Works of Robert Boyle*, Vol. 3, page 128. A. Millar (1744).

on Respiration” in which he showed that if a burning candle and an animal be put together in a bell jar both will expire sooner than either one alone. Mayow seems to have been the first to recognize that breathing brings the air into contact with the blood. He wrote: “Air loses somewhat of its elastic force during respiration by animals as also in combustion. One must believe that animals, like fire, remove from air particles of the same nature.”⁵ Mayow’s death at the age of thirty-four delayed the development of true conceptions of respiration for nearly a hundred years.

The Gases of Respiration

In 1754 a young Scottish medical student at the University of Edinburgh, named Joseph Black, published his dissertation for his M.D. degree on the subject of magnesia and quicklime, substances in which he was specially interested because the medicines in vogue for the cure of gallstones all seemed to derive their efficacy from quicklime. He had discovered that a cubic inch of marble yielded about half its weight of pure lime and “as much air as would fill a vessel holding six wine gallons.” His lectures were published after his death from his manuscript notes, and his biographer wrote in the preface: “It was not only a most unexpected and curious thing to find that a matter so solid and impenetrable as marble could appear in the form of air, and this air be again put into our hands in the form of marble; but . . . this air can be poured from one jar into another like as much water; and when it is poured out on a candle, or even on a fire in sufficient quantity, they are extinguished in an instant, as if water had been poured on them. . . . It has also been discovered that this air, so destructive and salutary, is forming in vast quantities every moment around us.”⁶ He called it “fixed air,” a little later to be identified as carbon dioxide. He also found that limewater was made cloudy by breathing into it through a tube, as well as by shaking it in a jar in which a candle had just gone out, and concluded that the breathing of animals changes “common air” into “fixed air.”

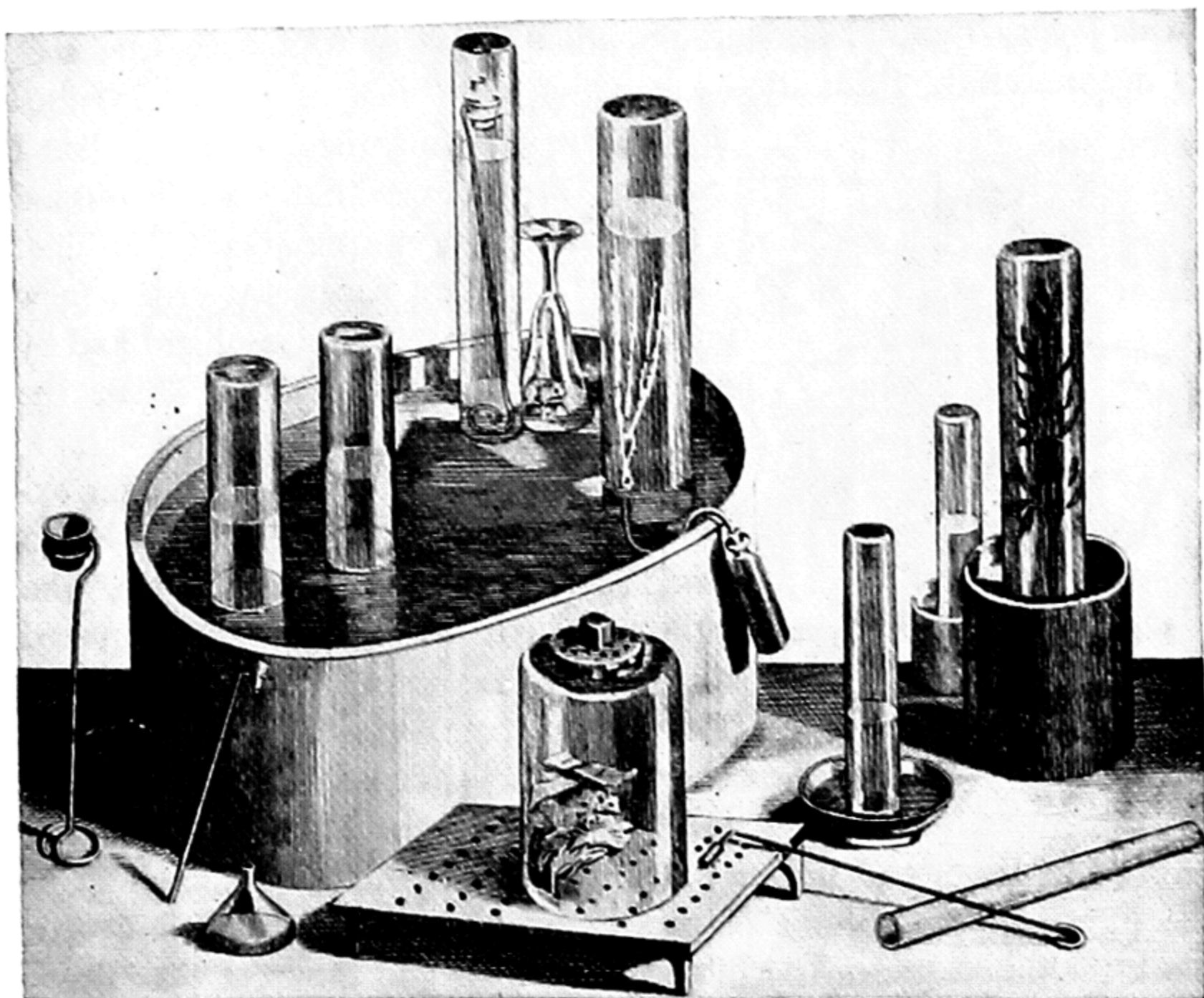
While Black was winning renown as a professor in the University

⁵ Lusk, Graham. “History of Metabolism.” Barker’s *Endocrinology and Metabolism*, Vol. 3, page 10. D. Appleton and Co. (1922).

⁶ Lectures on the Elements of Chemistry, delivered in the University of Edinburgh by the late Joseph Black, M.D., Professor of Chemistry in that University. Published from his manuscripts by John Robinson (1807).

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of Edinburgh and a devoted following as a practicing physician in the city, a dissenting clergyman in England, by the name of Joseph Priestley,⁷ was earning his living by acting as librarian for a rich patron but devoting all his spare time to chemical experimentation.



(Courtesy of the New York Public Library)

Fig. 2. Apparatus Used by Priestley

Plate 1 from *Experiments and Observations on Different Kinds of Air* (1790).

Priestley took a living plant (a sprig of mint) and put it into a closed receptacle in which a candle had already burned out. After several days another candle was introduced into the same jar and this time it did not go out but burned brightly. Soon after this, he took a jar, filled it with mercury, and carefully inverted it in a vessel containing mercury, so that no air entered the jar. He then introduced

⁷ He was born in Yorkshire, March 13, 1733, and came to the United States on June 4, 1794, living in Northumberland, Pennsylvania, until his death on February 6, 1814. His burning glass is preserved in the museum of Dickinson College, Carlisle, Pennsylvania.

through the opening, under the mercury, some red oxide of mercury, which rose and floated on top of the mercury inside the mouth of the jar. Upon this he converged the heat of the sun by means of a powerful burning glass, and this is how he described the result: "I presently found by means of this lens air was expelled from it (the mercuric oxide) very rapidly. Having got about three or four times the bulk of my materials, I admitted water and found that it was not imbibed



Fig. 3. Scheele's Apparatus Showing Bees in the Upper Chamber of a Glass Apparatus Filled with Oxygen

by it. But what surprised me more than I can well express was that a candle burned in this air with a remarkable brilliant flame."⁸ Priestley had discovered a new gas, given off by the growing plant and by the heated mercuric oxide, which the candle flame fed upon so readily.

At almost the same time a similar experiment had been performed by a Swedish apothecary named Scheele, who called the gas which he had discovered "fire air." Scheele next took two bees, put them in a chamber with a little honey, connected the chamber with a glass cylinder filled with the "fire air," and immersed its lower end in limewater. Day by day the limewater rose in the tube and the volume of gas diminished, until at the close of a week the limewater nearly filled the cylinder and the bees were dead. The "fire air" had been used up by the bees and the carbon dioxide given off by them was absorbed by the limewater which filled the space originally occupied by the "fire air."

Respiration a Measure of Food Burning in the Body

Priestley and Scheele were both in communication with a brilliant young French nobleman, Antoine Laurent Lavoisier, a member of the French Academy of Science. At their urgent request, he repeated their experiments, confirming the discovery that "fixed air" was carbon dioxide and giving to "fire air" the name of oxygen. Lavoisier then proceeded on his own account to demonstrate how living animals

⁸ Priestley, Joseph. *Experiments and Observations on Different Kinds of Air*, Vol. 2, page 107. Thomas Pearson (1790).



(From a drawing by Mme. Lavoisier)

Fig. 4. Lavoisier in His Laboratory Making the First Measurements of Energy Expenditure by a Human Being

affect the air. He took a sparrow, shut it up in a small chamber and concluded from his observations that oxygen disappeared from the air and that after the animal had died the carbon dioxide which it produced could all be absorbed from the chamber by limewater. Then Lavoisier and the great physicist Laplace together took another step forward. They put a guinea pig into a chamber and measured for ten hours the carbon dioxide formed by its respiration. This was found to equal that produced by burning in a closed vessel 3.33 grams of carbon. Next the guinea pig was confined for ten hours in a chamber containing a known weight of ice, and the quantity of ice melted by the animal's body was determined. This required for its melting almost exactly the same amount of heat as was evolved in burning the 3.33 grams of carbon. The obvious conclusion was that the carbon dioxide formed by the guinea pig came from burning in its body the equivalent of 3.33 grams of carbon.⁹

Similar observations were subsequently extended to human subjects, and drawings made by Mme. Lavoisier from memory after her husband's death in 1794 show Lavoisier's associate, Seguin, sitting in a chair breathing through a mask into a series of globes by means of which the oxygen consumed and the carbon dioxide given off were measured. Lavoisier came to the conclusion that "respiration is only a slow combustion of carbon and hydrogen, which is similar in all respects to that which takes place in a lamp or lighted candle; and from this point of view the animals which respire are truly combustible bodies which burn and consume themselves."¹⁰ Because of his grasp of the significance of the respiratory process in relation to food, Lavoisier is accounted the father of the science of nutrition.

Section 2. METHODS AND APPARATUS FOR THE MEASUREMENT OF ENERGY TRANSFORMATION

Ice and Water Calorimeters

Lavoisier was the first investigator who applied the balance and the thermometer to the study of vital phenomena. His work with

⁹ A slight discrepancy was accounted for in the reduction of the guinea pig's body temperature by the cold.

¹⁰ Cited by Mathews, A. P. *Physiological Chemistry*, 5th edition, page 287. William Wood and Co. (1930).

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Laplace on the measurement of the heat production of a guinea pig has already been mentioned. After Lavoisier's death the French Academy offered a prize for further investigation and two young men, Dulong and Depretz, entered the lists. They improved upon Lavoisier's methods, putting small animals into a chamber surrounded by water to absorb the heat and weighing the carbon dioxide and the water given off from the animals' bodies. Dulong won the prize (1823), although Depretz's work appears now to have been somewhat superior.

The Measurement of Respiration

In 1849, Regnault, professor of physics at the University of Paris, with his assistant, Reiset, constructed an apparatus which enabled him to keep small animals respiring normally in an enclosed space. The animal was placed in a glass case containing a known quantity of oxygen, which was replenished as it was consumed, and the air in the apparatus was continually pumped through a solution which took out the carbon dioxide exhaled. By means of this device, Regnault was able to show that eating different kinds of food made a difference in the amount of oxygen used and in the amount of carbon dioxide excreted. He also noticed that the small animals absorbed more oxygen and produced more heat and more carbon dioxide in proportion to their size than did the larger ones—sparrows, ten times as much as chickens; that cold-blooded animals (fish and reptiles) consumed less oxygen per unit of body weight than warm-blooded animals; and insects consumed much more than reptiles. Regnault and Reiset hoped to study man in the same way, but the apparatus proved too expensive for them to construct.

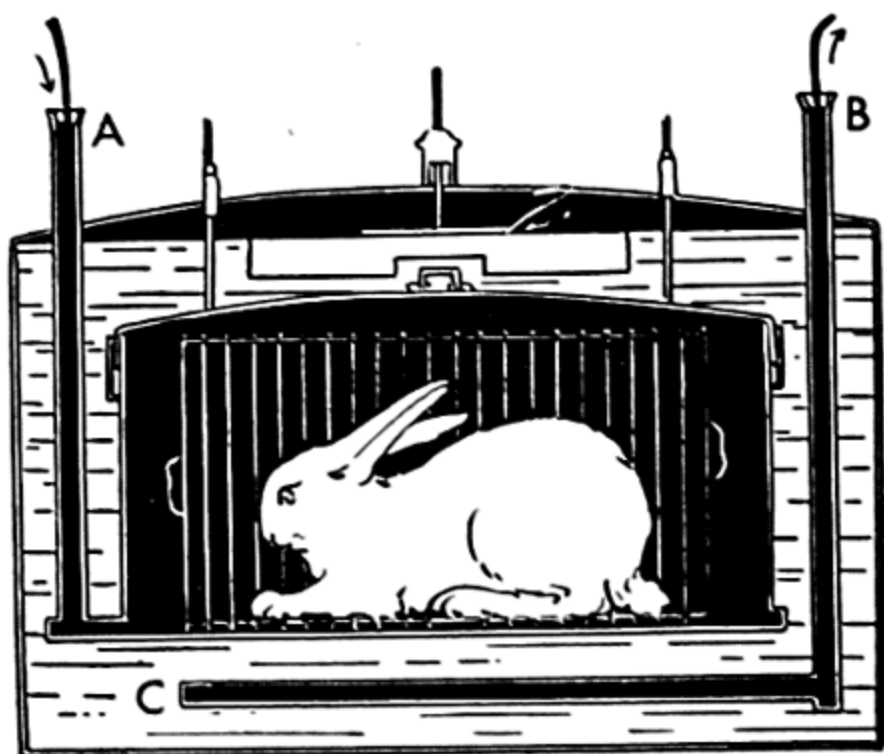


Fig. 5. A Water Calorimeter of 1823

The inner chamber containing the animal was submerged in a larger receptacle filled with water. Air entered at A, circulated through a coil under the inner chamber, and connected at C with the exit pipe B. Thermometers extending into the water recorded the rise in temperature caused by the animal.

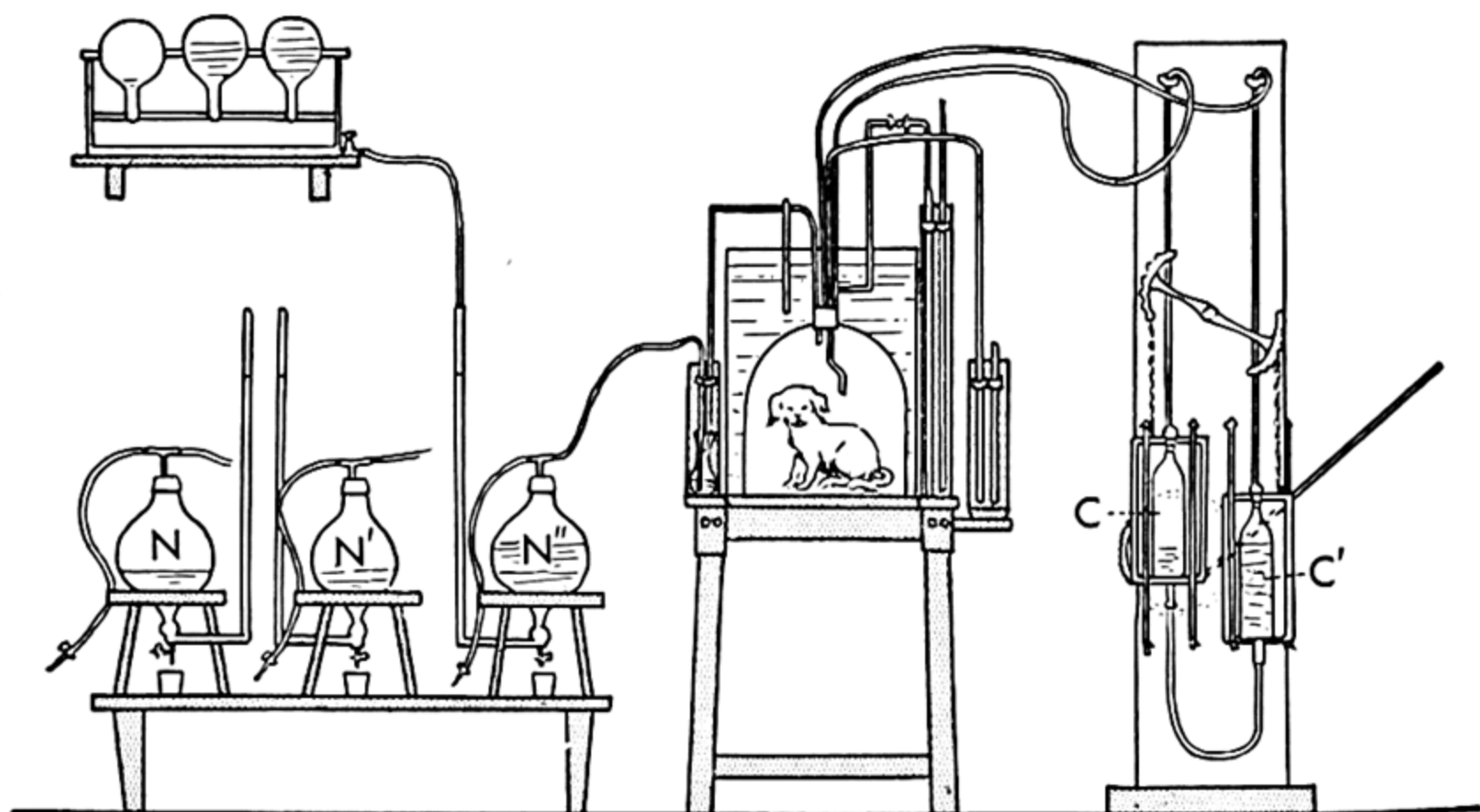


Fig. 6. Respiration Apparatus of Regnault and Reiset

Oxygen was supplied to the animal from a large flask, N". (N and N' are other flasks in reserve.) Water pressure from the flasks above at the left drove the oxygen into the apparatus. An exit tube from the chamber containing the animal was connected with bulbs for absorbing carbon dioxide, C and C'. (From *Annales de Chimie et de Physique*, Series 3, Vol. 26, Plate III, 1849.)

The Nature of Body Fuel

Liebig, born at the opening of the nineteenth century, was the first to understand clearly that the substances oxidized in the body are organic (carbon-containing) compounds of three types, protein, fat, and carbohydrate; and he showed that 1 gram of fat requires for complete combustion 2,050 milliliters of oxygen, and 1 gram of starch 832 milliliters—values nearly those in use today.

The Regularity of Heat Production

Bidder and Schmidt, two Germans working at the University of Dorpat (then in Russia), at about the same time (1850), concluded that for every species of animal there is a typical minimum of necessary metabolism, which is apparent in experiments when no food is given. "The extent of the respiration, like every other component of the metabolism process, is to be regarded as a function of one variable, the food taken, and one constant, a distinctly typical metabolism, which varies with the age and sex of the individual. This factor characterizes every animal of given race, size, age, and sex. It is just

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as constant and characteristic as the anatomical structure and the corresponding mechanical arrangement of the body.”¹¹

The First Respiration Chamber

Ten years later, Voit, then professor of physiology at the University of Munich, suggested to the physicist Pettenkofer, head of the hygienic laboratory of the city of Munich, that he devise a respiration apparatus which would accommodate a fairly large dog. Pettenkofer aspired to work with men, however, so he constructed (1862) an airtight chamber as large as the stateroom of a steamer, in which a man could live with comfort. It was ventilated by means of pumps which drew air from the outside. The air was drawn through the chamber, and at the point of exit samples were measured, after having been passed through suitable solutions for the removal of carbon dioxide and water.

Voit and Pettenkofer, working together with this apparatus, established many points hitherto uninvestigated or obscure. Rubner, later one of the masters of the science of nutrition, found, while working as a pupil in Voit's laboratory, that the energy values to the body of starch and fat were equal to the heat produced by burning them in a special apparatus for heat determinations, called a calorimeter; but that the energy value of protein was different, since it could not be burned as completely in the body as in the calorimeter.

The Law of Conservation of Energy in the Animal World

Rubner became professor of physiology at Marburg and in 1892 in his own laboratory evolved a calorimeter large enough for a dog, which very accurately measured the heat production of the animal. This was connected with a Pettenkofer-Voit respiration apparatus, and the heat measured by the calorimeter exactly corresponded (within 1 per cent) to the heat calculated from the measurement of the oxygen intake, carbon dioxide output, and losses of energy-bearing material in urine and feces. Thus, one hundred years after its initial conception by Lavoisier, Rubner established by animal experimentation the fundamental law that energy is neither created nor destroyed in the animal body.

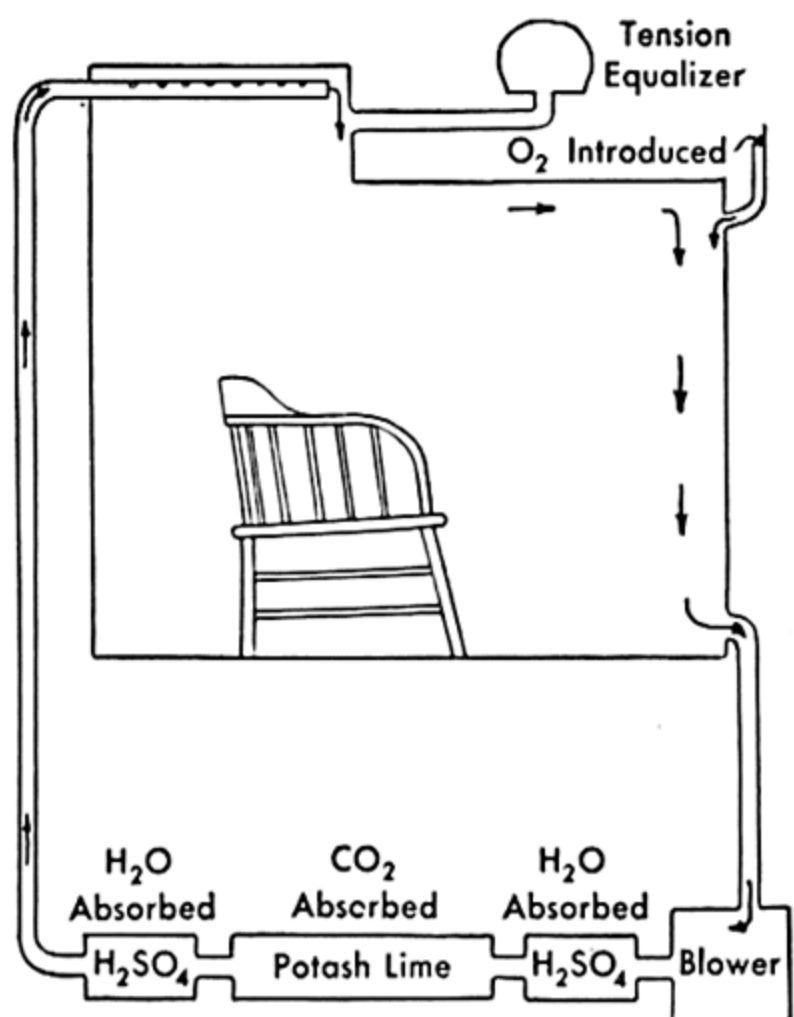
¹¹ Lusk, Graham. "History of Metabolism." Barker's *Endocrinology and Metabolism*, Vol. 3, page 63. D. Appleton and Co. (1922).

The Respiration Calorimeter in the United States

While Rubner was engaged in these researches in Germany, Atwater, also at one time a pupil of Voit and later professor of chemistry at Wesleyan University, Middletown, Connecticut, began to work upon a respiration calorimeter which was brought to perfection in association with the expert physicist, Rosa. This calorimeter enabled him to carry out on man such experiments as Rubner was conducting on dogs. The respiration part embodied the principles of the Regnault-Reiset apparatus; the heat measuring part depended upon removing the body heat as fast as produced by means of a current of cold water, thus maintaining a comparatively constant temperature in the chamber.

Improvements were soon instituted by Benedict, and the Atwater-Rosa-Benedict respiration calorimeter developed.

Briefly, this apparatus consists of an airtight copper chamber surrounded by zinc and wooden walls with air spaces between. Provision is made for preventing exchange of heat between the metal walls and for heating or cooling the inner air space as desired. The outer air space protects against heating or cooling by the air of the laboratory. By means of thermoelectric junctions between the copper and zinc walls connected with a delicate galvanometer, the temperature of each wall is measured at frequent intervals during an experiment to preclude any possibility of the results being influenced by the passage of heat through the walls of the chamber. The ventilation is



(Courtesy of Dr. F. G. Benedict)

Fig. 7. Chair Type of Respiration Calorimeter

The arrows show the circulation of the air, which is kept in motion by the blower. Water (H_2O) is absorbed by the sulfuric acid (H_2SO_4) and carbon dioxide (CO_2) by the potash lime.

so regulated as to keep the temperature of the incoming and outgoing air the same. The heat evolved by the subject is absorbed by a current of cold water passing through a pipe coiled near the ceiling

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of the chamber, except for a small amount which leaves as latent heat of water vapor. The amount of heat removed from the chamber is computed from the amount of water that flows through the pipe and its rise in temperature during its passage.

The space for the subject is large enough for him to stand or lie at ease and move about somewhat. It is furnished with metal chair, table and bed. An opening in the front, sealed during the experiment, serves as both door and window. In the opposite wall is a smaller aperture, used for passing food, drink, excreta, etc., into or out of the chamber. Tightly fitting caps close each end. There is a telephone for communication with persons outside.

The perfecting of the respiration calorimeter for human experiments opened a new era in nutrition in this country. Calorimeters were built in Washington by the United States Department of Agriculture; at the Pennsylvania State College, by Armsby; in New York, by Lusk, for Cornell University Medical College and the Russell Sage Institute of Pathology; in Boston, by Benedict, for the Carnegie Institution of Washington. These men and their associates made signal contributions to our knowledge of energy requirements, many of which will be referred to later.

Portable Respiration Apparatus

The conclusive demonstration, by means of the respiration calorimeter, that energy calculated from the amounts of carbon dioxide excreted and oxygen absorbed by a man lying quietly in the apparatus exactly equals the heat given off by his body in the same period, has made it possible to dispense with the actual measurement of body heat (direct calorimetry) in a great many experiments, and to rely upon studies of the respiration (indirect calorimetry).

The principle upon which Regnault and Reiset built their apparatus in 1850 is that upon which modern respiration apparatus is constructed. Zuntz, long chief of the Agricultural College in Berlin, made a portable respiration apparatus to measure the energy expenditure of a man walking at sea level or on the snow fields of Monte Rosa. This apparatus was subsequently used with great success by one of his pupils, Magnus-Levy, for the study of respiration in disease. This type of apparatus was further developed in 1918 when F. G. Benedict, then director of the Nutrition Laboratory of the Carnegie Institution of Washington, located in Boston, produced his portable

respiration apparatus which is easy to operate and inexpensive enough to be within the reach of many laboratories. This enables many students with relatively little training in physics and chemistry to have first-hand experience in determining energy expenditure from oxygen consumption.

The Benedict portable respiration apparatus depends upon the principle that the oxygen breathed in by a subject is used in response to a need of the body and is not stored. Consequently, the oxygen consumed is a measure of the amount of combustion going on in the body. The ratio of the amount of the carbon dioxide produced in the process to the amount of oxygen consumed is called the respiratory quotient. It has been found that if a normal person in good health has fasted 12 to 15 hours this ratio is practically constant, giving a respiratory quotient of 0.82. Under these conditions 1 liter of oxygen consumed represents 4.825 calories. The subject must always have fasted until all food has left the alimentary tract so that the oxygen consumed may represent the burning of body fuels in the same proportions in every case. When this preliminary fasting period is not practicable, recourse must be had to some type of apparatus in which both oxygen intake and carbon dioxide output can be determined and the respiratory quotient calculated exactly.

When the Benedict portable respiration apparatus is used the subject is connected with it by means of a soft rubber mouthpiece so devised as to prevent escape of air through the lips, while the circulation of air through the nose is prevented by a spring or a screw clip. The person breathes from a current of oxygen-enriched air which is kept in circulation by a set of valves which allows the current to go in only one direction. The air is constantly purified by the removal of carbon dioxide as it passes through a container of soda lime. It is kept supplied with oxygen by means of a spirometer into which, before the experimental period, oxygen is run from a storage cylinder. As the oxygen is used up by the subject the spirometer falls. In the Benedict portable respiration apparatus shown in Fig. 8, measurement of the oxygen consumed is made by means of a pen attached to the spirometer which writes on a moving drum covered with paper. The drum is driven by a clock and revolves at a constant rate. The paper is ruled vertically so that the time required for the pen to move from one vertical line to the next is one minute. Horizontal lines correspond to the change in position of the spirometer as the

oxygen is consumed, the space between two lines indicating the withdrawal of a definite amount of oxygen. As the spirometer rises and falls, the pen records also the rate and depth of respirations. A line

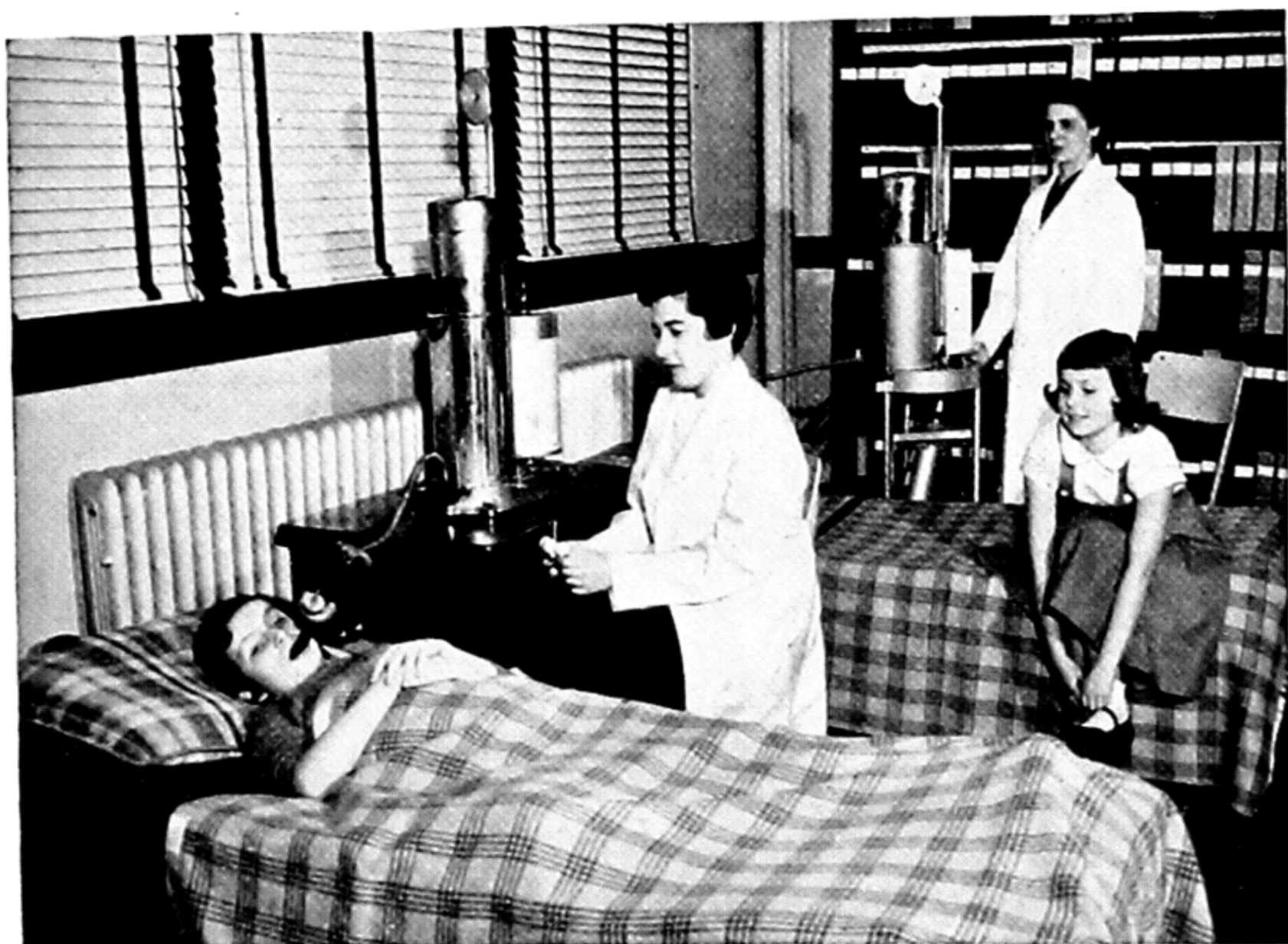


Fig. 8. Preparation for the Measurement of Basal Metabolism Using the Benedict-Roth Portable Respiration Apparatus in the Nutrition Laboratory, Teachers College, Columbia University

Note that observer is about to place clip on subject's nose.

drawn along the points which mark the end of each expiration will give the difference between the first and last readings, as shown in Fig. 9. To get the true value of oxygen, corrections must be made for the temperature, the atmospheric pressure, and the moisture in the spirometer.

A less expensive type of respiration apparatus, designed by Dr. Benedict for the use of students, is shown in diagram in Fig. 10. A rubber bathing cap is substituted for the metal spirometer. This is inflated with oxygen from a cylinder of the compressed gas, until a small button attached to the bathing cap exactly touches a disc on the metal rod above it. As the oxygen is consumed by the subject, the button soon fails to touch the mark, and the oxygen is replaced

by pumping in room air, using a small bicycle pump of known volume for the purpose. The air pumped in will measure exactly the oxygen

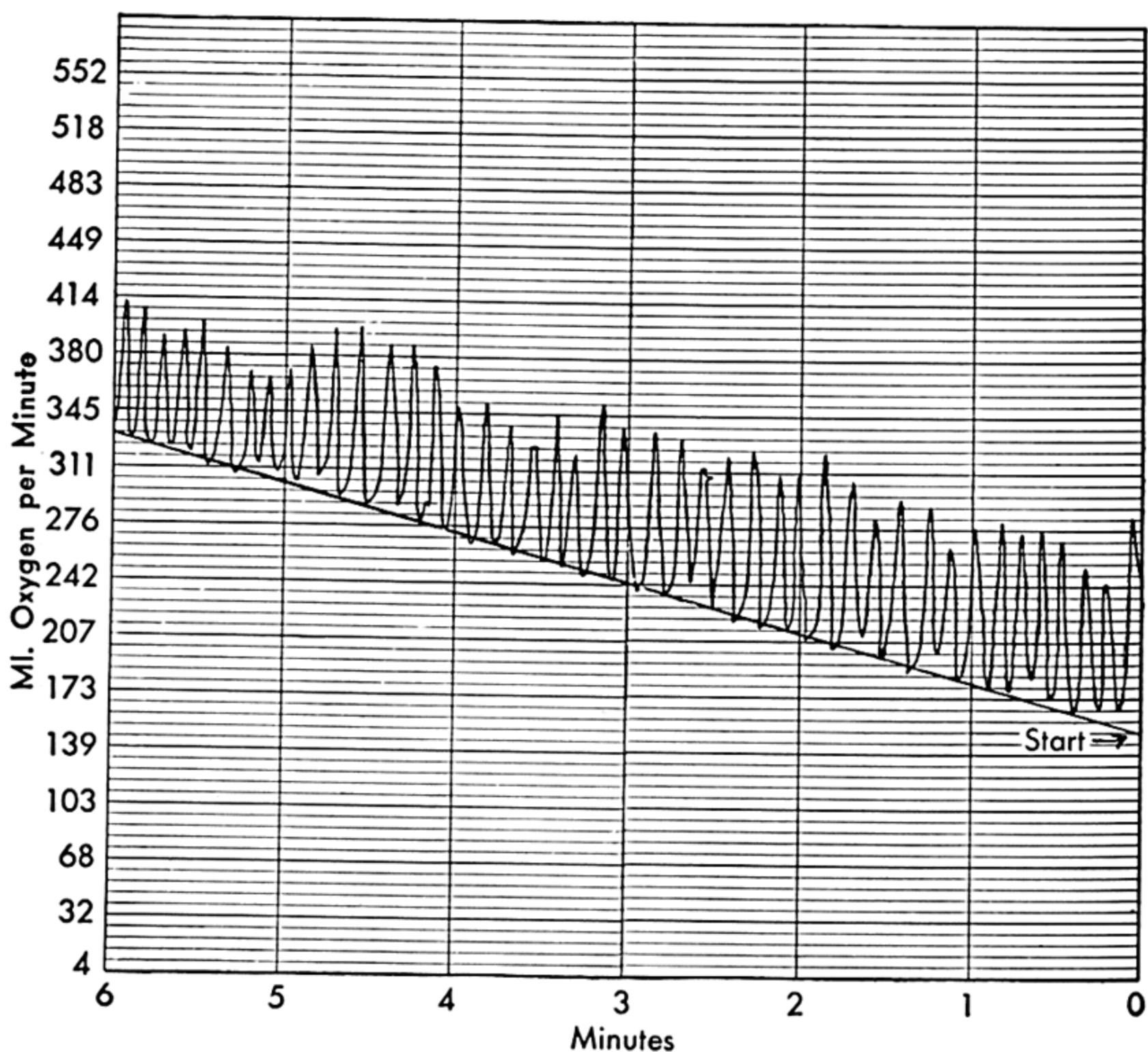


Fig. 9. Respiration Record in a Basal Metabolism Test

The tracings mark the rise and fall of the spirometer with each inhalation and exhalation. The difference between the start and the finish gives the volume of oxygen consumed per minute.

removed, since gases at the same temperature and pressure have the same volume. Knowing the capacity of the pump and the number of strokes required to inflate the cap to the disc, we can calculate the amount of oxygen consumed in a given time. To find from this the number of calories expended, we apply the well-established fact that under basal metabolism conditions 1 liter of oxygen consumed will correspond to 4.825 calories. For example, a man of average weight, sitting attached to the apparatus for ten minutes, will consume about 2.5 liters of oxygen, and the calories corresponding will be 12, or 72 calories per hour. A description of an apparatus of this type made

and used by high school students will be found in the dissertation by Bingham noted in the references at the end of the chapter.

Kofranyi and Michaelis of the Max Planck Institute in Germany reported in 1940 the development of a light-weight apparatus con-

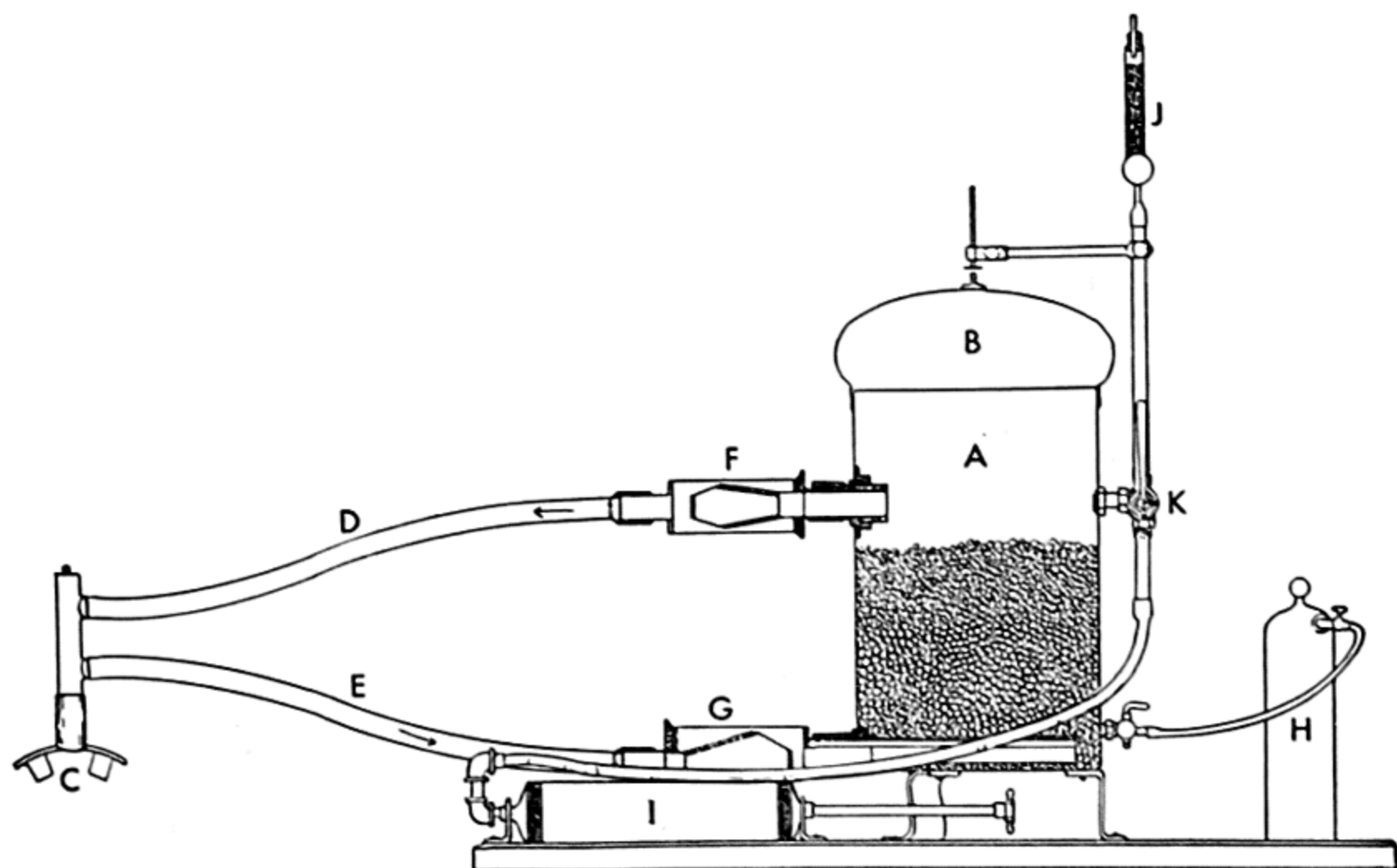


Fig. 10. Diagram of Benedict's Student Respiration Apparatus

A. Metal can containing soda lime to absorb carbon dioxide.

B. Bathing cap inflated so that button almost touches marker above it.

C. Rubber mouthpiece.

D and E. Rubber tubes connecting can and mouthpiece.

F and G. Valves controlling direction of air current.

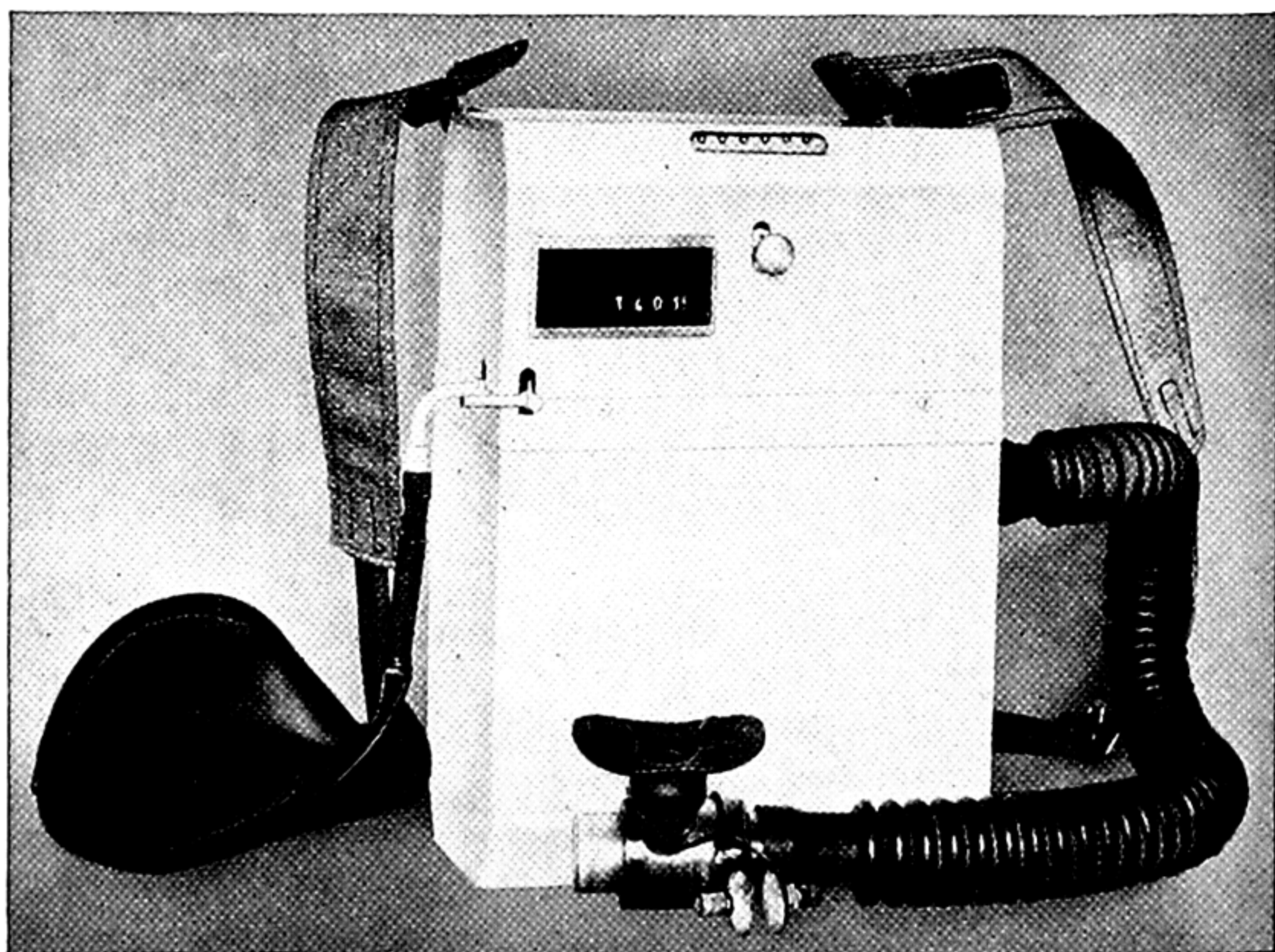
H. Oxygen tank from which a supply of pure oxygen for starting an experiment is introduced into the can.

I. Pump by means of which additional air is supplied to can; it is drawn in through a moist sponge in tube J to saturate the air with water vapor.

K. Valve through which air from pump is admitted to can.

sisting of a dry gas meter which measures the volume of the expired air and from which samples of the expired air can be collected (Fig. 11). These samples, which can be regulated in size according to the fraction desired, are collected in football bladders and later analyzed for oxygen and carbon dioxide content. Atmospheric air, which the subject inhales, is also analyzed for these two gases. Thus the consumption of oxygen and production of carbon dioxide can be determined and the energy expenditure calculated. This apparatus is carried on the subject's back as shown in Fig. 20, page 58.

Results with standard types of respiration apparatus agree closely with those obtained with the respiration calorimeter, making their use in schools and hospitals highly practical.



(Courtesy of Drs. E. A. Müller and H. Franz, Max Planck Institut für Arbeitsphysiologie, Dortmund, Germany)

Fig. 11. The Kofranyi-Michaelis Respiration Apparatus

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The Basal Metabolism and Factors Affecting It

In the foregoing chapter we have seen that the dream of Lavoisier has come true. We have arrived at the point where we can measure with great precision the amount of oxidation which is going on in the animal body under any given set of conditions. Not only because of its historical interest is it fitting to begin our study of nutrition with the energy exchange, but also because, quantitatively speaking, the greatest demand which we make upon food is that it shall supply us with calories. There are other food factors equally important qualitatively to be discussed in their turn, but in ordinary daily life few of these can be secured independently of the energy supply, while all of them may and most of them must be obtained incidentally to it.

Practically, our task is to learn first how many calories we need and then to see how, by intelligent choice of foods which yield them, we may make them the carriers of every other dietary essential. This will eventually involve much study of individual foods, for, in the words of Armsby, long the distinguished director of the nutrition research laboratory at Pennsylvania State College, the problem of rationing a people "is very far from being so simple a thing as merely supplying a certain number of calories of energy or grams of protein. Questions of palatability, of dietary habits, of market facilities, and of costs of fuel, labor, transportation, and marketing both in agricultural and manufacturing industries, all these have to be considered."¹ But we shall pursue our study of these far more successfully if we have as a foundation a clear conception of energy requirements

¹ Armsby, H. P. *Conservation of Food Energy*, page 13. W. B. Saunders Co. (1918).

and how they may be met. In approaching the study of the energy requirement we have to bear in mind the fact that energy expenditure varies greatly with conditions of existence: it rises rapidly, for instance, when a man who has been sitting in a railroad station and has fallen asleep while waiting for his train awakens to find it pulling out, and bolts through the doorway on a dead run to catch it; it falls when an athlete who has been doing a hundred-yard dash crosses the line and sinks down to rest after his sprint.

In order to systematize the factors causing such variability, we shall take as our starting point a state of energy expenditure which is practically constant from hour to hour for a given individual and is known as the basal metabolism.

Section 1. THE BASAL METABOLISM

The term metabolism is used broadly for all the chemical changes which take place within the body under the influence of living cells. Some of these changes are concerned with the construction of body substance from materials taken from the environment as food, some with the maintenance of essentially stable tissues in an organism in which flux is the law of life, and some with the use by the body of energy-yielding materials for its internal and external activities. It is with the last of these that we are now concerned, and the general term energy metabolism is employed to designate those chemical processes which have to do with the combustion of fuel to run the human machine.

If we measure the energy expenditure of an adult each morning after he awakens, but before he rises from his bed and begins to take food or to dress, we shall find in the course of a week a striking similarity in the daily returns, and we may be surprised at the amount of "internal work" which is going on. In warm-blooded animals, as Regnault observed in his pioneer investigations, the resting energy expenditure is always higher than in cold-blooded ones. The warm-blooded animal seems to live on a spendthrift plane so far as energy is concerned. This is correlated with the fact that he depends upon the heat which is a result of his internal activities for the maintenance of a uniform temperature for the body cells, despite fluctuations in the temperature of the environment. There is an irreducible minimum of energy expenditure, without which life is impossible. The absolute

minimum is not reached in the waking but in the sleeping state; it is, however, more practical to take as the line of reference the energy output of the subject awake, lying quiet, comfortably warm, and relaxed, 12 to 15 hours after the last meal. This is called the basal metabolism.

The Basal Metabolism of the Adult

The basal metabolism of a man weighing 143 pounds or 65 kilograms is about 1,560 calories for the 24-hour day; that of a woman weighing 121 pounds or 55 kilograms, about 1,320 calories. If we put this in terms of a few common food materials, we shall perhaps realize its significance a little better.

FOODS YIELDING CALORIES EQUAL TO
THE BASAL METABOLISM FOR ONE DAY

<i>Foods</i>	<i>Man</i>		<i>Woman</i>	
	<i>Measure</i>	<i>Calories</i>	<i>Measure</i>	<i>Calories</i>
Bread	4 slices	252	3½ slices	221
Butter	3½ tbsp.	350	1½ tbsp.	150
Lamb chop	1 med. fat	356	1 med. fat	356
Milk	1 pt.	333	1 pt.	333
Orange	1 med.	70	1 med.	70
Potato	1 med.	100	1 med.	100
Shredded wheat	1 biscuit	100	1 biscuit	100
Total		1,561		1,330

To be strictly accurate, the intake and the outgo of energy will not quite balance with the eating of this food, because food itself has a stimulating effect which raises the basal energy expenditure. This will be discussed further in Section 1 of the next chapter.

Basal Metabolism in Terms of Body Weight and Body Surface

It is often most convenient to think of the basal metabolism in terms of body weight. If Mr. Jones and Mr. Brown are both the same age, but one weighs 150 pounds (68 kilograms) and the other 180 pounds (82 kilograms), the total basal metabolism of the one will be about 1,632 calories and of the other about 1,968 calories. These figures do not tell us that the basal metabolism of these men is really the same, but if we divide total calories by body weight we get the same figure, 24 calories per kilogram per day.

For the young adult of average size it has been found that the basal metabolism lies very close to 1 calorie per kilogram per hour. At this rate, a man weighing 65 kilograms would have for 24 hours a basal metabolism of 1,560 calories ($1 \times 65 \times 24$).

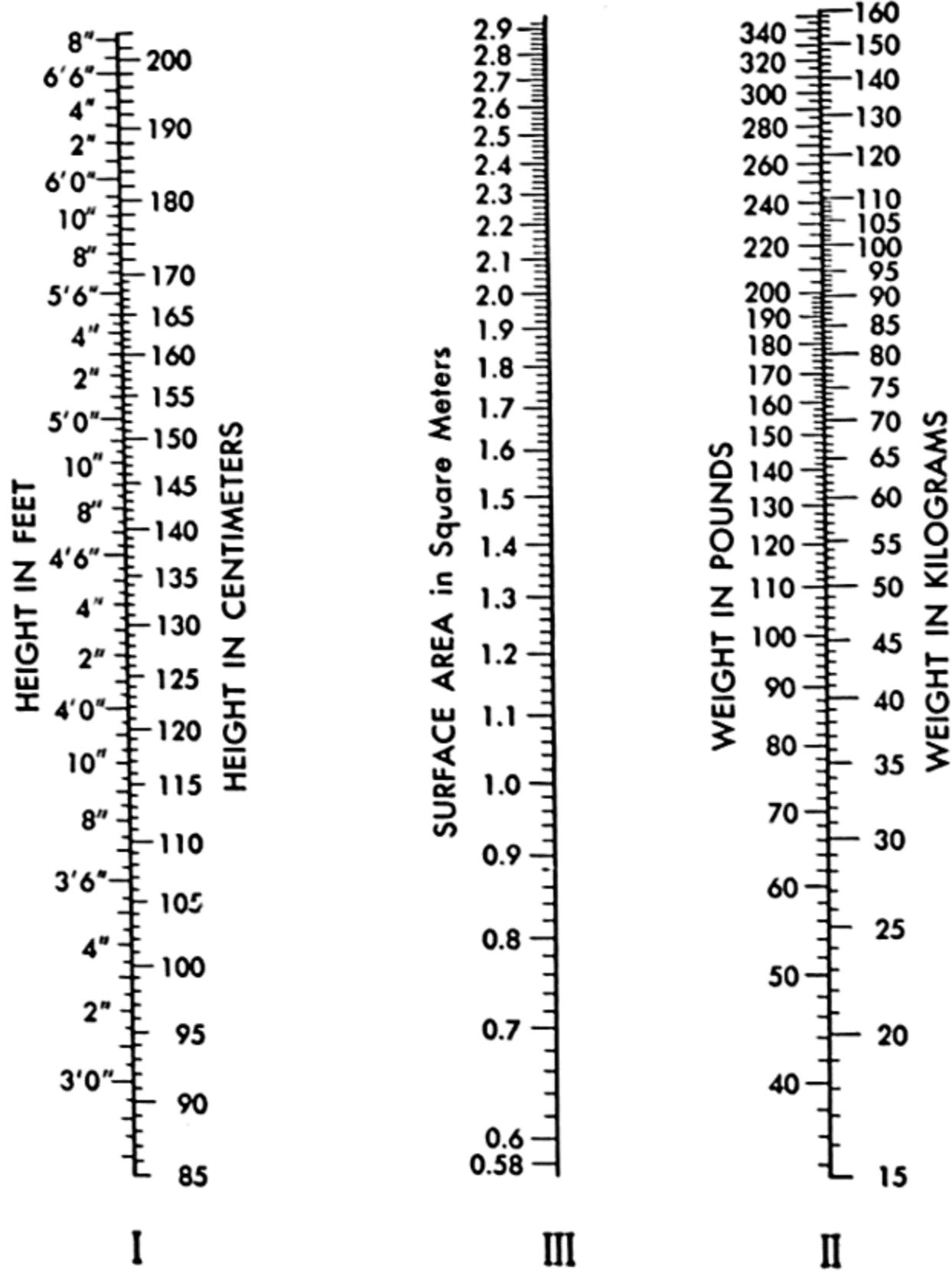


Fig. 12. Nomogram for Determining Surface Area from Height and Weight Prepared by Boothby and Sandiford of the Mayo Clinic from the DuBois Surface Area Chart

To determine the surface area locate height on line I and weight on line II, draw a line connecting these two points, and read surface area where this line intersects line III.

Scientifically, a more accurate prediction of the basal metabolism can be made on the basis of the surface area of the body. DuBois developed a chart for determining the body surface from height and

weight after making actual measurements of the surface area of a large number of persons. The subject to be studied was dressed in close-fitting underwear, thin socks and gloves, and a section of the leg of a knitted garment made a covering for head and neck. Upon this foundation strips of manila paper were pasted to make a complete mold of the body. This mold was carefully removed in sections, then these were cut into pieces small enough to lie flat, and photographed on weighed paper. The imprints were cut out and weighed, and their weight compared with that of the whole sheet of paper whose area was known, thus making it easy to determine the surface area of the entire body or of any desired portion.

From the DuBois chart Boothby and Sandiford constructed the nomogram on page 23 (Fig. 12). Comparison of the results of actual determinations of the basal metabolism of large numbers of normal individuals with those given by either the surface area chart or the nomogram have shown agreement in the majority of cases within plus or minus 10 to 15 per cent. Reasons for divergence from the average rate are discussed in the following sections.

A man in good health weighing 143 pounds (65 kilograms) and standing 5 feet, 7 inches high (170 centimeters) will have, according to the nomogram, a body surface of 1.76 square meters and if he is twenty to forty years old, his basal metabolism according to the table on page 34, will be close to 37.8 calories per square meter per hour. His total basal metabolism for 24 hours will then amount to 1,597 calories ($37.8 \times 1.76 \times 24$). A healthy woman between thirty and forty years of age weighing 121 pounds (55 kilograms) and 5 feet, 2 inches tall (157 centimeters) will have a body surface of 1.57 square meters and a basal metabolism of 34.0 calories per square meter per hour, making a calculated total of 1,281 calories per day ($34.0 \times 1.57 \times 24$). These figures may be summarized as follows:

AVERAGE BASAL METABOLISM OF A MAN AND A WOMAN
THIRTY TO FORTY YEARS OF AGE ²

	<i>Weight</i> <i>Kg.</i>	<i>Surface Area</i> <i>Sq. M.</i>	<i>Calories per</i> <i>Sq. M. per Hr.</i>	<i>Calories per</i> <i>24 Hrs.</i>
Man	65	1.76	37.8	1597
Woman	55	1.57	34.0	1281

² For other ages see page 34.

The basal metabolism is fairly constant for individuals of the same age and sex in a state of health.

Section 2. FACTORS AFFECTING THE BASAL METABOLISM

Influence of Size and Shape

For most practical purposes we can disregard fatness or thinness in adults if we estimate basal metabolism on the basis of body surface. If, however, we make calculations in terms of body weight, we shall find that we cannot apply our average of approximately 1 calorie per kilogram per hour without some error in those cases in which the individual is taller, shorter, thinner, or fatter than the average. Basal metabolism being more closely correlated with surface than with weight, we must consider what effect changes in size have on the relationship between it and weight. A small body has a greater surface in proportion to mass than a large one. If we take two balls, one of them 1 inch in diameter and the other 2 inches, the first (A) will have a surface of 3.14 square inches and the other (B) of 12.57 square inches, while the volume of the first will be 0.52 cubic inch and that of the second 4.19 cubic inches. So the surface of the smaller ball in proportion to its volume is 3.14 to 0.52 or 6 to 1 and that of the larger ball is only 12.57 to 4.19 or 3 to 1. This means that if two animals alike in shape had the same relation to each other as these spheres, the smaller would produce twice as much heat per unit of weight as the larger.

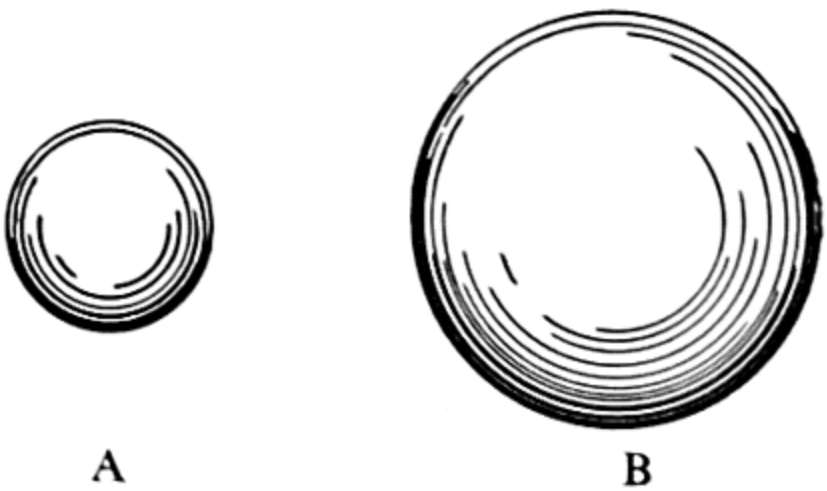


Fig. 13. Two Balls Showing How, Shape Being the Same, Difference in Size Affects the Amount of Surface

	A	B
Diameter	1 inch	2 inches
Surface area	3.14 square inches	12.57 square inches
Volume	0.52 cubic inches	4.19 cubic inches
Surface to volume	6:1	3:1

In a similar manner we may inquire how the relationship between mass and surface is affected by shape. If we take a pound of modeling clay and make it into a cylinder (A) with a diameter of 2.6

inches it will have also a height of 2.6 inches; if we take another pound and make it into a cylinder with half the diameter of (A), this one (B) will have a height of 12.2 inches. While the weight is the same in both cases, the difference in shape results in a difference in surface area,

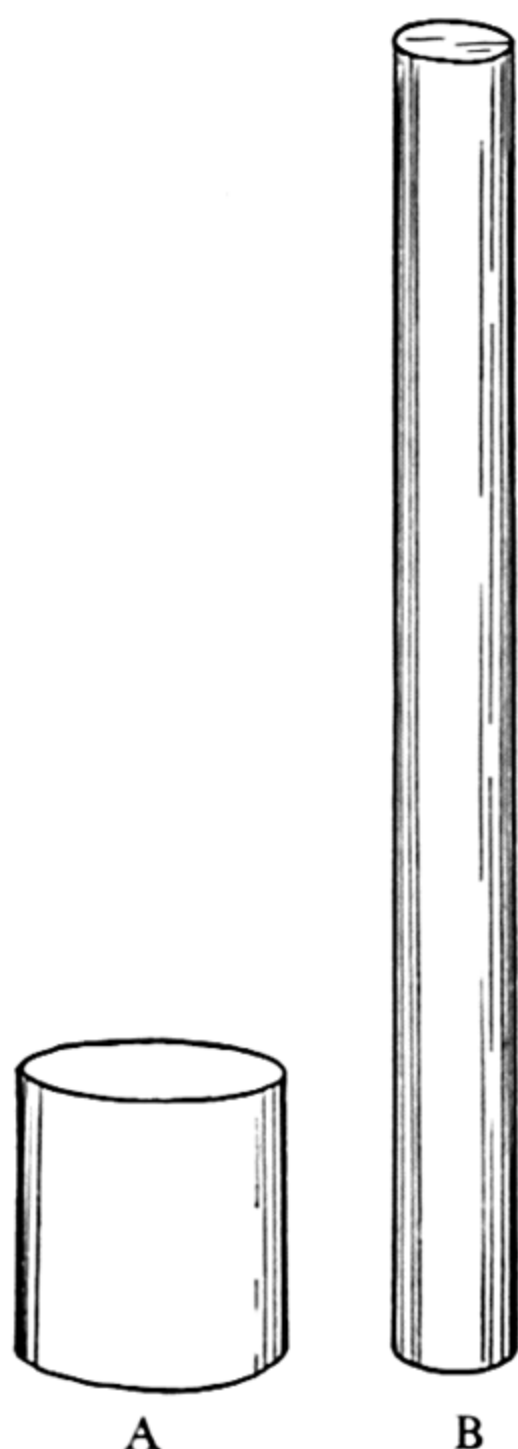


Fig. 14. Two Cylinders Showing How, Weight Being the Same, Difference in Shape Affects the Amount of Surface

	A	B
Weight	1 pound	1 pound
Diameter	2.6 inches	1.3 inches
Height	2.6 inches	12.2 inches
Surface area	31.8 square inches	48.3 square inches

the tall and slender figure having a surface exposure of 48.3 square inches, while that of the shorter figure is only 31.8 square inches. In other words, the tall "thin" figure has half again as much surface area as the short "fat" one of the same weight.

If we take two men of about the same age and the same body weight but one much taller than the other and determine the basal metabolism of each for 24 hours, we can see (page 27) how this is related to body weight and to surface in human beings.³

On the basis of body surface the metabolism is the same, but when we calculate this to calories per kilogram of body weight, the taller figure shows a metabolism higher by 9 per cent.

A similar comparison may be made between individuals of the same height but differing in body weight.

Influence of Body Composition

Two individuals of exactly the same weight and height and consequently of the same surface area may still differ somewhat in the intensity of their basal metabolism. The ex-

³ The data used in this illustration are taken from Benedict, F. G. "Factors Affecting Basal Metabolism." *Journal of Biological Chemistry*, Vol. 20, page 282 (1915).

planation lies in the fact that the great seat of energy exchange is the muscle tissue, and that bone, fat, and water, while inert so far as energy metabolism is concerned, still play a part in determining weight. The large fat person not only has a size and shape favorable to an economical energy expenditure per unit of weight, but also has less muscle tissue in proportion to his bulk. Athletes, having by vigorous exercise rid themselves of surplus fat and built up firm muscle tissue, show a basal metabolism about 6 per cent higher than nonathletic individuals carefully paired with them as to size and shape. Women, with a higher proportion of body fat, have on the basis of body surface an average metabolism about 10 per cent lower than that of normal men.

BASAL METABOLISM OF TWO MEN OF THE SAME WEIGHT BUT DIFFERENT HEIGHT

Subject	Age, Yrs.	Height, Cm.	Body Weight, Kg.	Surface Area, Sq. M.	<u>Basal Metabolism for 24 Hrs.</u>		
					Total	Cal. per Sq. M.	Cal. per Kg.
Mr. B.	41	183	83.1	2.06	1,802	875	21.7
Mr. C.	36	169	83.0	1.89	1,655	876	19.9

Influence of Undernutrition

The most comprehensive study of the effects of chronic caloric undernutrition is that of Keys and his co-workers at the University of Minnesota during World War II. Thirty-two conscientious objectors served as subjects. They lived in the Laboratory of Physiological Hygiene for a year. During the first three months the subjects lived on a controlled adequate diet. Then followed six months of semistarvation and next, three months on the adequate diet of the prestarvation period. During the prestarvation or control period the subjects maintained their average body weight on an average daily intake of 3,492 calories. Their activities consisted of a regular schedule of laboratory and housekeeping duties, 20 miles of walking each week, and participation in an educational program. During the semistarvation period which followed immediately after the control period their energy intake averaged 1,570 calories daily (slightly less than half the control value). Their diet consisted of cereals, potatoes, cabbage, and turnip—foods commonly used in cases of famine in Northern Europe. At the end of six months on this diet the subjects had lost 24 per cent of their body weight and showed symptoms characteristic of famine

victims such as weakness, depression, anemia, edema, polyuria, and marked slowing of the heart (bradycardia). They suffered a marked loss of strength and endurance as the period progressed and said they felt as if they were rapidly growing old. They felt weak, tired easily, moved cautiously, and reduced unnecessary movements to a minimum.

At the end of the 24-week period the basal oxygen consumption was reduced by 39 per cent and the body weight by 24 per cent. Per square meter of body surface, the average drop in the oxygen consumption was 28 per cent, while per kilogram of body weight, the reduction was only 15 per cent. These differences are explained by the change in proportional composition of the body, decreases in the fat content resulting in relative increases in bone and water content. Allowing for the increase in water, these investigators found that the basal values were only about 10 per cent below those of the pre-starvation period, a small but significant drop in the basal metabolic rate per unit weight of the active tissue of the body.

When the men were returned to living on the prestarvation (control) diet the basal metabolic rate rose in parallel with the food intake and the gain in body weight, but before body weight was fully restored and for some time thereafter the basal rate exceeded that of the prestarvation period. When body weight had been restored after 20 weeks of refeeding the basal metabolism per unit of body weight averaged 13 per cent above the average of the prestarvation period.

A full report of this investigation will be found in *The Biology of Human Starvation* by Keys, Brozek, Henschel, Michelsen, and Taylor published by the University of Minnesota Press, 1950, and there is an abstract from this book in the American Medical Association *Handbook of Nutrition*, Chapter XIX, page 409 (1951).

Influence of Muscle Tension

In making a determination of basal metabolism on any person, every effort is made to have as complete muscular relaxation as is possible. This is one reason why the basal metabolism is determined early in the morning; even under quiet conditions, tension becomes higher as the day progresses. If the person has risen from bed, dressed, perhaps traveled to the laboratory, he is required to lie quietly for a time to let the effect of exercise upon the tone of the muscles wear off. It is also important that he be in a calm frame of mind, as emo-

tion will raise the muscle tension. If proper precautions be observed in making laboratory tests, most of the determinations on normal individuals will fall within 10 per cent of the average.

Influence of Mental States

As has already been pointed out, the chief seat of energy exchange is the muscles. The seat of thought is the nervous tissue. Do we increase our energy expenditure when we think? The classic demonstration that mental activity does not materially change the metabolic rate was made by Benedict and Carpenter with the respiration calorimeter. In it 22 young college men took three-hour examinations and later sat the same length of time copying printed material which required no mental effort. The metabolism was only slightly greater in the first case than in the second.

Some very interesting measurements of the effect of mental exertion were made by Dr. and Mrs. Benedict. The mental effort consisted in solving, without writing or talking aloud, certain mathematical problems, a typical one being to multiply 73 by 47. The problems were given orally, and at the completion of each the subject touched a telegraph key. Problem followed problem as rapidly as solved. The general effect of the mental exertion was the same in all of the seven cases. It was found that the mental effort of multiplying "in the head" increased the metabolism 3 or 4 per cent. Commenting on this work, they said: "The professor absorbed in intense mental effort for one hour has an extra demand for food or for calories during the entire hour not greater than the extra needs of the maid who dusts off his desk for five minutes. The cloistered scholar at his books may be surprised to learn that the extra calories needed for one hour of intense mental effort would be completely met by the eating of one oyster cracker or one-half of a salted peanut."⁴

Tashiro, a Japanese investigator working at the University of Chicago, demonstrated by an exceedingly delicate apparatus for measuring carbon dioxide excretion that when an impulse is transmitted along a nerve the carbon dioxide production may be increased to two and one-half times that of the resting nerve. If we should assume all the nervous tissue in the body to be as active as this, the total carbon dioxide output would not equal that produced by lifting one's hand

⁴ Benedict, F. G., and Benedict, C. G. "The Energy Requirement of Intense Mental Effort." *Science*, Vol. 71, page 567 (1930).

to one's face. As the nervous tissue is only about 2 per cent of the total body weight, even if its metabolism increased with thinking, the total would be small, the highest estimate of the energy metabolism of the brain being only 10 per cent of the resting metabolism. Students sometimes ask, "Why do we get hungry when we study?" forgetting that they would get hungry anyway. They are generally more active in their periods of relaxation and actually need more food on holidays than on study days.

Aside from the question of the basal metabolism of the nervous system itself, mental states are, however, not without influence upon the muscles. As Stiles says, "an emotional experience is much more than a cerebral phenomenon." It is a form of exercise. Increased heart action, more rapid respiration, tenser muscles are characteristic of more than one emotional state, and in experimental hypnosis, normal men and women have responded to suggestions inducing fear or joy with increased heat production which seems to be the direct result of the changed emotional condition. The evidence on this point is still meager and here, again, the average increase is under 10 per cent.

Influence of Internal Secretions

One of the very fascinating fields of modern physiology is that embracing the endocrine glands, which deliver to the blood internal secretions containing hormones (sometimes called chemical messengers) which are quite as important as the nervous system in keeping all parts of the body working harmoniously together. A number of these hormones have been isolated and their chemical structure investigated. Most of them are found to be related to proteins. They are chemically very powerful so that minute quantities introduced into the circulation produce remarkable effects. For example, absence in childhood of thyroxine, the hormone of the thyroid gland, results in failure to grow physically or mentally; a superabundance of one of the several hormones of the pituitary gland brings about abnormal growth and a giant may develop; or again, failure of the pancreas to produce insulin results in impairment of the body's power to use its fuel foods in the normal way, and a disease marked by undernutrition, called diabetes mellitus, ensues.

Of all the glands of internal secretion, the thyroid has the closest connection with the energy exchange. In health it may be regarded

as responsible in large measure for the constancy of the normal basal metabolism. In diseases of the thyroid characterized by overproduction of thyroxine, the chemical processes of the body are speeded up, and the basal metabolism may in very severe instances increase as much as 75 per cent. Moderately severe cases will show increases of from 40 to 50 per cent, while in mild cases the rise may still be from 15 to 30 per cent. On the other hand, a subnormal production of thyroxine causes a lowering of the basal metabolism, in severe cases amounting to a fall of as much as 30 per cent. So characteristic of thyroid disturbance is a change in the basal metabolism that the determination of it is one of the routine measures in the clinical diagnosis of thyroid disease. Deviations of 10 to 15 per cent from the normal average are not by themselves significant, such variation occurring in normal persons, and no single determination is ever to be regarded as conclusive. The amount and nature of the change must be studied in connection with all other factors in the situation.

In addition to a high basal metabolism, the patient suffering from hyperthyroidism is in a state of almost incessant movement. Consequently his total food requirement may be so high that only when resting in bed can he eat enough food to compensate for his high energy output. If he attempts any muscular work, this is done with difficulty and at a cost that may amount to twice the calories required for the same work by a normal man. Hyperthyroidism tends to bring the person very quickly to a state of undernutrition and the only remedy is reduction of the production of thyroxine by suitable treatment in which rest is always a prominent feature.

Adrenaline (also called epinephrine), a secretion of the adrenal gland, has an effect much less powerful than that of thyroxine. A single injection of 1 milligram of adrenaline will cause an increase in the energy metabolism of only 50 calories which reaches its height in an hour whereas the effect of the same dosage of thyroxine may be spread over a period of several weeks and cause an extra energy production of 1,000 calories. Professor W. B. Cannon of Harvard University has shown that under stress of emotional states, as fear, rage, or pain, the adrenals are stimulated to an increased output of adrenaline, the heart action becomes more vigorous, blood is shifted to the organs immediately necessary for muscular action, and these are put under greater tension, so that the body has power to carry out any of the actions that may take place under the force of these

emotions. All this means a temporary increase in the basal metabolism. Muscular action alone causes some increase in adrenaline production, but the most profound effect is from emotion and vigorous muscle action together. Cold also stimulates adrenal activity, which in turn causes increased heat production as discussed under influence of temperature. After complete removal of the adrenal glands there is great relaxation of the whole muscular system and the basal metabolism falls.

The basal metabolic rate of human beings has been found to be somewhat low in many cases of subnormal functioning of the pituitary gland or hypophysis. The discovery of a specific hormone (the thyrotropic) in the secretion of the anterior lobe has made it evident that the influence of the pituitary gland on metabolism is exerted chiefly through the stimulation of thyroid activity by this hormone. Another hormone of the anterior lobe (the adrenalotropic) influences the adrenal gland and may also be a factor in changes in the basal metabolic rate in pituitary disturbance.

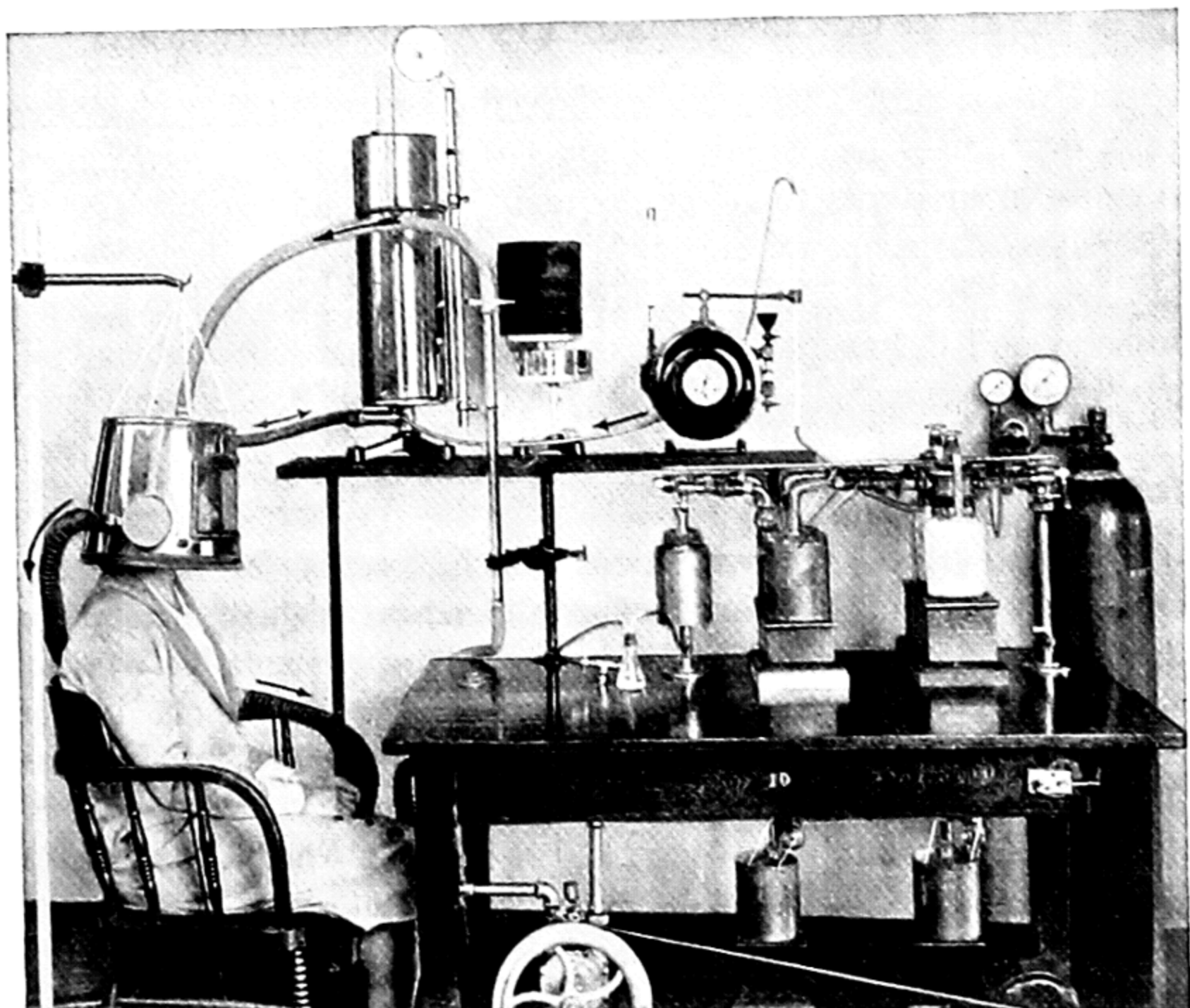
Influence of Age

The influence of age during the period of growth will be considered in Chapter 4. This discussion is confined to adults. Harris and Benedict from a statistical study of adult men and women concluded that for each year of age after twenty a man's decrease in basal heat production amounts to 7.15 calories per day, i.e., if at twenty a man has a basal metabolism of 1,735 calories per day, at twenty-one it would be 1,728 calories; at twenty-two, 1,721 calories. For a woman, the decrease is estimated to be only 2.3 calories per day for each year of age. While this annual fall is slight, in forty years it results in an appreciable lowering of the basal energy expenditure.

A study of 23 aged women was made by Benedict and Meyer⁵ in a home for elderly women in Boston. All but two of the subjects were at least seventy years old and ten ranged from seventy-eight to eighty-six years. A helmet type of apparatus (Fig. 15) was used—a pail-shaped vessel with a small window for the benefit of the subject being inverted over the head and made airtight about the neck by a thin rubber collar. The usual connections were made with a spirometer supplying oxygen, the carbon dioxide was removed by means of jars

⁵ Benedict, F. G., and Meyer, M. H. "The Basal Heat Production of Elderly Women." *Proceedings of the American Philosophical Society*, Vol. 71, page 143 (1932).

of soda lime, and a fan served to keep the air in the closed circuit in circulation. The average basal metabolism for the group was 729 calories per square meter of body surface per day as compared with



(Courtesy of Carnegie Institution of Washington)

Fig. 15. The Helmet Type of Apparatus in Use with Subject Sitting Up. This Apparatus Can Also Be Used for the Basal Metabolism Determination with Subject Lying Down

the Harris-Benedict average of 760 calories per square meter per day for women from fifty to sixty years of age. It is interesting to note that the total basal metabolism of the ten women seventy-eight years and over was close to 1,000 calories per day regardless of considerable differences in body weight.

In a study of several men over seventy-five years of age made by Aub and DuBois the heat production was found to be 10 to 14 per cent less per square meter of surface than the average for men between thirty and forty. The following table is based upon one given by them to indicate the trend with increasing age. Their figures have been

corrected in line with more recent findings indicating that the original ones for women were about 7.5 per cent too high and those for men about 4.5 per cent too high.

BASAL METABOLISM OF ADULTS AT DIFFERENT AGES

Age, Years	<u>Calories per Sq. M. per Hour</u>		<u>Calories per Sq. M. per Day</u>	
	Men	Women	Men	Women
18-20	39.2	35.3	941	847
20-30	37.8	34.4	907	826
30-40	37.8	34.0	907	816
40-50	36.8	33.5	883	804
50-60	35.9	32.6	862	782
60-70	34.9	31.6	838	758
70-80	34.0	30.7	816	737

Influence of Sex

The sex glands have secretions which account for certain sex characteristics, but no clearly defined differences in basal metabolism due to sex hormones have been produced experimentally. Women, as has already been stated, have a basal metabolism about 10 per cent lower than that of men of corresponding age. Menstruation has little influence, changes which occur ranging from 2 to 5 per cent. Castrated males tend to have the higher body fat which characterizes women as a class; but there is no evidence that a total absence or diminished activity of the sex glands regularly causes a decrease in the metabolic rate.

Influence of Pregnancy

A woman's gain in body weight during pregnancy totals, on the average, 20 to 25 pounds. During the early months weight tends to remain stationary, while in the last three months gains range from 3.5 to 5.5 pounds per month. About half the gain is due to general increase in body tissue on the part of the woman herself. A detailed study of a pregnant woman made by her husband ⁶ showed that after the fourth month the basal metabolism rose slowly, until a few days before delivery it was about 23 per cent above what it was in the fourth month. More recent studies have indicated that the increase is about 15 to 20 per cent above normal. Murlin, formerly Professor

⁶ Root, H. F., and Root, H. K. "The Basal Metabolism during Pregnancy and the Puerperium." *Archives of Internal Medicine*, Vol. 32, page 411 (1923).

of Nutritional Physiology in the University of Rochester, found that the energy metabolism of a mother and child together a few days after parturition just about equaled that of the mother before confinement. He found a striking instance of this relationship between parent and offspring in two experiments with a dog that bore at one time a litter of one pup and at another a litter of five; the extra calories attributable to the lone pup were 46 (164 per kilogram) and to the five pups, 258.5 (165 per kilogram).⁷ Interpreting his observations in terms of body weight, Murlin estimated that for the human mother the basal energy metabolism per kilogram per hour was only about 4 per cent higher than for the same woman before pregnancy. For practical purposes the increase in basal metabolism may be assumed to parallel fairly closely the increase in weight.

Section 3. THE RELATION OF TEMPERATURE REGULATION TO BASAL METABOLISM

A frog's body temperature changes as the thermometer rises or falls. On a cold day the animal is cold; on a warm day it is warm. When its body is cold, metabolism is reduced; when its body is warm, metabolism is increased. The difference between 39° F. (winter) and 86° F. (summer) may cause an increase of 400 per cent in the amount of carbon dioxide produced. A man's body temperature, on the other hand, is practically constant (close to 98.6° F.), regardless of the external temperature. Changes in the normal person's body temperature in the course of a day scarcely exceed 1 degree Fahrenheit, while in a single hour the temperature of the environment may rise or fall many degrees. In Texas, a drop of 40° F. in one hour is not uncommon; in New York in August one may step from the hot summer street into the artificially cooled theater. How do these changes in temperature affect the basal metabolism?

To get to the root of the matter, we must first rule out the influence of housing and clothing, which may greatly modify the situation. About 80 per cent of the heat usually produced in the body is lost through the skin.

The path of heat elimination varies with the environment. There is little evaporation of water when the temperature is low; and, since

⁷ Murlin, J. R. "Normal Processes of Energy Metabolism." Barker's *Endocrinology and Metabolism*, Vol. 3, page 622. D. Appleton and Co. (1922).

there is no opportunity for loss of heat by radiation and conduction when the surrounding atmosphere has a temperature as high as or higher than the body, water evaporation must remove all the heat.

Effect of High Temperature Including Fever

What happens when the temperature of the environment becomes equal to that of the body? If the person is free to perspire and the humidity of the atmosphere does not interfere with the evaporation of the moisture on the skin, there will be no change in body temperature or in the rate of heat production; for as the evaporation of water cools the skin the blood beneath it will be cooled and, mingling with that from the interior of the body, will check the tendency to rising temperature. On the other hand, if we put a man into a bath at body temperature, there will be no way of getting rid of body heat—no chance for radiation, conduction, or evaporation; but the body will continue to produce heat and consequently the body temperature will rise. A bath at 42° C. (107.6° F.) has been shown to cause an increase in the oxygen consumption amounting to 15 per cent. Studying the basal metabolism under a variety of conditions in which body temperature was above normal (fevers), DuBois has calculated that the increase in energy expenditure in fever amounts to 7.2 per cent for every degree Fahrenheit. What this means is readily seen from the following estimates on a man whose basal metabolism is 1,700 calories:

INCREASES IN ENERGY EXPENDITURE WITH RISE IN
BODY TEMPERATURE

<i>Rise in Temperature, Degrees Fahrenheit</i>	<i>Increase in Energy Expenditure, Per Cent</i>	<i>Extra Calories Due to Elevation of Temperature</i>
1	7.2	122
2	14.4	245
3	21.6	367
4	28.8	490

For the average bedridden person with normal temperature we ordinarily make allowances above the normal basal metabolism of 10 per cent for the movements inevitable through the 24-hour day, and of 10 per cent of the sum of basal metabolism and cost of activity for the influence of food (specific dynamic action). For an individual case the calculation would be as follows:

ENERGY EXPENDITURE OF A BEDRIDDEN MAN
WITH NORMAL TEMPERATURE

	<i>Calories</i>
Basal metabolism	1,700
Allowance for activity	170
Allowance for influence of food	187
	<hr/>
Total for 24 hours	2,057

The fever patient must have an additional allowance for increased expenditure due to elevation of temperature on the basis of 7.2 per cent for each degree Fahrenheit and if restless, a higher allowance (20 to 30 per cent) for activity. For the above man with fever the day's requirement would be estimated thus:

ENERGY EXPENDITURE OF A MAN WITH A FEVER,
BODY TEMPERATURE ELEVATED 2° F.

	<i>Calories</i>
Basal metabolism	1,700
Increase for 2° F. rise in temperature	245
	<hr/>
Total basal metabolism	1,945
Allowance for activity (20 per cent)	389
Allowance for influence of food	233
	<hr/>
Total for 24 hours	2,567

With only a moderately high fever the food requirement may easily reach more than 2,500 calories per day. Whether it is wise to try to meet this need fully with food or whether it is better for a time to let the patient burn his own body reserves is a point which the physician must decide for the individual case. But full realization of what it means for a patient to be burning 2,500 calories a day of his own body substance is important. If the energy requirement can be covered by food, the patient will be less weakened by his disease. This is most strikingly shown in the case of typhoid fever. There was a time when it was thought necessary to give very little food in spite of the fact that typhoid is a disease causing a long wasting illness. The patient became so weak and emaciated that convalescence was almost as dangerous as the febrile state. But in 1909 Shaffer and Coleman, using the calorimeter of the Russell Sage Institute of

Pathology at the Bellevue Hospital in New York City, demonstrated that it was possible to feed typhoid patients a diet high enough in calories and protein to prevent all loss of body substance. The treatment of typhoid was revolutionized and patients fed according to Shaffer and Coleman's plan actually gained weight during the progress of the disease. The task of feeding typhoid patients is, however, peculiarly difficult since in addition to the allowance suggested for rise in temperature, there must be an allowance of from 50 to 100 per cent more calories for the special purpose of preventing waste of the body tissues.

The metabolism in malarial fever is influenced by the chills as well as by the fever. The changes are best illustrated by one of the cases studied by Barr and DuBois, also with the calorimeter of the Russell Sage Institute.

ENERGY CHANGES IN A CASE OF MALARIAL FEVER

	<i>Per Cent above Normal Basal Metabolism</i>
One hour before severe chill, no fever	+14
Rising temperature before chill	+21
Violent chill (40 min.)	+216
Rising temperature after chill	+80
High constant temperature after chill (41.2° C.)	+71

In the preliminary period the heat output is only a little if any above normal, beginning to rise as the temperature rises before the chill. During the chill the violent muscular exertion increases heat production enormously. In the period following the chill the temperature is rising, but the percentage of energy output falls as compared with that during the chill. Later the temperature declines and gradually both metabolism and temperature return to normal.

In pulmonary tuberculosis there may or may not be fever. When the temperature is normal the basal metabolism is usually though not always normal; but whenever the body temperature rises the energy output follows the general law and rises proportionately. Before studies of the energy metabolism in this disease had been made, the tendency was to feed very high calorie diets, but since it is desirable to reduce the strain on the lungs from the work of respiration as much as possible, it is now thought that the total calories should be no more than necessary to meet the energy requirement, usually not over 2,500 calories per day. Here again the diet needs to be care-

fully prescribed and faithfully administered, as the appetite is frequently poor, and digestion apt to be disturbed. DuBois⁸ sums up the situation thus: "It is perfectly extraordinary how much food can be given to fever patients by a good nurse. In the first place, she takes scrupulous care of the mouth and teeth, realizing that no patient cares for food if his mouth is dry, his tongue cracked and his teeth dirty. . . . She studies the likes and dislikes of the individual patient and does not try to force foods which are distasteful even in health. . . . She seizes opportunities at night to feed the patient when he is awake. Above all, she uses tact and employs persuasion or gentle firmness as the case demands."

Effect of Temperatures below That of the Body

If we start our study with a nude man resting in quiet air at 30° C. (86° F.) and proceed to reduce the temperature, what changes will occur in his heat production? Perspiration begins to decrease and the peripheral blood vessels to contract so that less heat is lost. At temperatures only slightly under 30° C. there will be little change in the metabolism. As the thermometer continues to fall the feeling of "tone" develops in the muscles, meaning that the muscles, contracting more vigorously, are generating more heat. How greatly the sudden stimulation of cold may affect the metabolism can easily be demonstrated by a cold shower. It was found that taking a shower for three and a half to five minutes in water at 15° C. (59° F.) more than doubled the oxygen consumption and that it took an hour and a half for the metabolism to return to normal. This increase in response to the stimulus of cold is called "chemical regulation" of temperature, in contrast to those changes in heat loss which involve no change in metabolism and are grouped under the term "physical regulation."

How the chemical regulation is accomplished was shown by Cannon and his associates. When cold water or crushed ice is introduced into the stomach quickly, heat-producing factors must be set at work to restore body temperature. In other words, a "heat debt" is incurred which must be paid. Such a debt may be met by doing extra work, i.e., by shivering, but it may also be met, if not too great, by increased secretion of adrenaline, which causes a faster metabolic rate in response to the body's need for heat. When shivering occurs,

⁸ DuBois, E. F. *Basal Metabolism in Health and Disease*, 3rd edition, page 441. Lea and Febiger (1936).

the rise in heat production is sudden and much more marked and it may nearly double the energy output. When conditions are such as to induce shivering, they are also such as to induce a faster rate of adrenal secretion. Extra heat production as a consequence of a larger output of adrenaline would therefore coexist with the extra heat production due to muscular activity.

Chemical regulation is involuntary, but we may voluntarily increase our heat production by increased muscular work. The man waiting on the curb for a bus on a cold morning stamps his feet and claps his hands; the one walking to work sets off at a brisker pace than on a balmy day. The range of physical regulation is widely extended by clothing and housing, which will be referred to later.

Effect of Body Fat on Regulation of Body Temperature

A layer of subcutaneous fat acts much like a woolen or a fur garment. Rubner studied a dog when it was thin and again after it had been fattened and found that, while there was no difference at 22° C. (71.6° F.), nearly a fifth more heat was produced by the dog in its thin than in its fat state if the temperature was reduced to 15° C. (59° F.). When a thin man steps into a refrigerator his heat production is increased much more than is that of a fat man when he enters it. At low temperatures, a layer of subcutaneous fat is very valuable in preventing rapid loss of body heat and saving the body from burning fuel merely to keep warm.

With rising temperatures, fat hinders heat loss and a fat man's body temperature is more likely to rise than a thin man's, because the former cannot easily dispose of heat by radiation and conduction. Therefore, the fat person is more liable to heat prostration than the thin individual and needs to be cautious about exercise which will produce heat when getting rid of it is difficult.

Relation of Season and Climate to Temperature Regulation

Besides temperature, we must consider wind and humidity as factors in the regulation of body temperature. A young woman exposed to the windy blasts of April in England was found to have nearly doubled her resting metabolism; adult men and women exposed to an Alpine winter climate in sheltered sun-boxes showed increases in metabolism varying from 38 to 79 per cent above their basal rates in London; and children responded with still greater increases, varying from 72 to 225 per cent.

It must be remembered, however, that when any muscular activity, such as walking, for instance, furnishes heat as a by-product there is lessened need of special "chemical regulation." While a cold plunge induces shivering (chemical regulation), a swim in the same water may leave the body glowing because the work of swimming is severe enough to result in the production of heat in excess of that needed to maintain body temperature.

Humidity facilitates heat loss when associated with low temperature and wind, but hinders it when associated with high temperature, especially if the atmosphere be quiet. The fat person suffers most from high temperature with high humidity, as what little cooling power the perspiration may have does not act as effectively through a covering of fat. In such a person, rise in body temperature easily occurs, with a resultant rise in the basal metabolism, adding further to the heat to be dissipated. Such a person works with difficulty in hot, humid weather, as each movement adds its quota of heat to the general discomfort.

Effect of Clothing and Housing

Man's triumph over every climate is due to his ingenuity in extending the realm of physical regulation through his dwelling and his clothing. Even a rude hut protects from wind, wet, and heat, while a modern, air-conditioned house may maintain the same temperature when the thermometer outside stands at zero as when it stands at "ninety-five in the shade." Wherever there is cold, the home of civilized man is equipped with some kind of heating device, which greatly limits the work his muscles are called upon to do to keep him warm; and in the hot season the electric fan or air conditioning keep the temperature of the modern house below that of the outer air.

The variety of ways in which clothing is related to a life almost devoid of shivering or sweltering is too numerous to record here. Silk, cotton, wool, fur, and synthetic fibers such as nylon, dacron, and others or thick or thin cloth all have a part to play. It is wonderful to think that an Arctic explorer can lie down and sleep to awaken warm and even perspiring after an Arctic night with the thermometer 60° below zero (F.) and the wind blowing a gale, provided there is not the tiniest hole in his garment. The smallest opening would be fatal as it would mean a heat loss which no chemical regulation could ever offset. It has been reported by Dr. Laughlin on his return from a trip to Alaska sponsored by the Arctic Aeromedical Labora-

tory of the United States Air Force that caribou skin outer garments, when the hair is left on the skin, are lighter and warmer than any garments thus far developed for the United States armed forces in the Arctic.

In everyday life in temperate zones, those conditions which facilitate heat loss from the body are likely to raise the metabolism unless counteracted by clothing and housing. The seashore, with a cold moist wind, is ideal for cooling the body rapidly. This is not necessarily a disadvantage, as the higher muscle tonus may be accompanied by a better appetite and the habit of eating more food may become established so that it persists upon the return home after a seaside holiday. People who need to be fattened may benefit from having their basal metabolism raised by the climate, provided they can have enough food to more than meet the increased demand. When clothing is scanty and fails to conserve body heat and at the same time food cannot be found to meet the increased metabolism, the body is in danger of drawing upon its own substance for fuel. The poor suffer doubly from inadequate clothing and shelter because their food needs are thus increased. Their thinly clad children are apt to be undernourished, whereas the thinly clad children of the rich may benefit from this stimulus to life on a higher metabolic plane, provided they are fed intelligently.

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The Energy Requirement of Adults

In the preceding chapter we have learned about the basal metabolism and various factors and conditions which may affect it. While the basal metabolism constitutes an important and strikingly constant quota of the energy expenditure, it is not the sole determinant of the energy requirement. No one could live long on the basal level. No one could remain absolutely quiet all the time; no one could subsist without food which itself, as already noted, increases the energy output. In ordinary daily life what allowances must be made for the taking of food and for the muscular movements which are an inevitable part of existence? If we determine these, we can add them to the basal metabolism and thus obtain the total energy requirement of the adult.

Section 1. THE ALLOWANCE FOR THE INFLUENCE OF FOOD

Lavoisier was the first to note that eating food increased the amount of oxygen absorbed by a human being. Sixty years later, Bidder and Schmidt gave a starving cat all the meat it would eat and found that the oxygen absorption and carbon dioxide output were doubled in consequence. Ten years after this (1862), Pettenkofer and Voit fed a dog different quantities of meat and found that the larger the meat meal the greater the combustion within the organism. They then tried fat and starch and found that the increase with fat was smaller than with starch, and neither had any such marked effect

as meat. Rubner carried this investigation much further and learned that bones, water, and meat extracts had no effect. Hence he called this stimulating effect of food, which he found to be of a different order of magnitude for protein, fat, and carbohydrate, "specific dynamic action."

Rubner demonstrated that man responds in a similar fashion by performing another experiment, in which a man was given a calorie allowance, first of sugar and then of meat, 20 per cent above his basal energy expenditure without food. The sugar alone raised the output 2.2 per cent in 24 hours, while the meat alone raised it more than 25 per cent, or more than ten times as much. If the food fed is practically all carbohydrate, the rise of metabolism following its ingestion will be about 6 per cent of the total, i.e., for every 100 calories an extra 6 must be allowed for the whipping up of cell activity as this food is absorbed from the intestinal tract and begins to circulate in the blood stream. The effect of fat is about the same, 6 to 14 per cent, but that of protein is very marked, amounting to at least 30 per cent.

We are most interested in the effect of a mixed diet, because we do not usually eat a single kind of fuel food by itself. DuBois has summarized the work of investigations made in the Nutrition Laboratory of the Carnegie Institution of Washington and in the Russell Sage Institute of Pathology. A very small breakfast (222 calories for men weighing 65 and 74 kilograms, respectively) increased the heat production 5.4 calories, or a little over 2 per cent of the total calories. A heavy breakfast (over 2,142 calories) increased it 111 calories (5.2 per cent), while a very heavy breakfast (3,936 calories) gave an increase of 290 calories (7.4 per cent).

The effect of a beefsteak by itself is strikingly shown in an experiment by Benedict and Carpenter, where approximately 9 ounces (418 calories) were eaten, with the result that the heat production was raised 139 calories, or one-third of the total energy value of the steak. These calories were lost as heat and were not available for any useful work in the body. DuBois aptly remarks: "In this manner some of the excess food is burned and wasted just as a surtax diminishes a large income."

There is one circumstance in which the "tax" may be returned to the citizen's own pocket, so to speak. On exposure to cold, there is, as we have already seen, a tendency for the metabolism to rise for the primary purpose of maintaining the normal body temperature. Now if meat be fed, the heat which is evolved can be turned to

account instead of being wasted. This was quite clearly shown by a series of experiments conducted by Lusk on a dog. The basal metabolism was determined at various room temperatures. At 30° C. (86.0° F.), it was about 56 calories per kilogram, while at 7° C. (44.6° F.) it was over 50 per cent higher. At ordinary room temperature, giving the dog 11 ounces of meat raised his metabolism from 56 to 76 calories, a waste of 36 per cent. When the temperature fell to 7° C., the basal metabolism rose to 86 calories per kilogram. Upon being given meat in the same amount as before, there was practically no increase in the heat production. The 20 calories which were a dead loss in the first instance, when no extra heat was needed, were turned to good account in the second case, in which heat equivalent to 30 extra calories was required.

More recent studies of the influence of food (specific dynamic action) have shown increases varying from 6 to 17 per cent. These increases are in any case a very small part of the total energy metabolism, and it is concluded by most investigators today that 10 per cent is probably a safe allowance on average mixed diets.

Section 2. ALLOWANCES FOR THE INFLUENCE OF MUSCULAR ACTIVITY

A person having his basal metabolism determined sometimes finds the eight to ten minutes a long time to keep still. Ordinarily, lying still in bed means turning over now and then, bending and unbending the legs, shifting arms and hands; such "activity" may easily add 10 per cent to the basal metabolism. When a person sits absolutely quietly in a chair, the metabolism will average 8 per cent higher than when lying down. However, no one will sit perfectly still for long. If one watches his neighbors "sitting still" for a short time, listening to the sermon in church or to a lecture in the classroom, he will find few who do not make a good many minor motions, as the following random studies show:

MOVEMENTS OF ADULTS "SITTING STILL"

<i>Person</i>	<i>Time</i>	<i>Hands to Face</i>	<i>Readjusting Position</i>	<i>Moving Hands</i>	<i>Moving Feet</i>	<i>Moving Head</i>	<i>Total</i>
Woman	25 min.	0	3	6	9	28	46
Woman	25 min.	16	5	27	2	17	67
Man	25 min.	8	4	26	1	10	49
Man	25 min.	2	1	3	0	5	11



(Courtesy of Dr. F. G. Benedict)

Fig. 16. Determining, by the Benedict Knapsack Apparatus, the Energy Cost of Sawing Wood

As soon as one begins to move about, as in walking even at a very slow pace, the expenditure becomes double that of "sitting at rest," and if one walks rapidly it may rise to four, five, or six times the sitting value.

Benedict and Parmenter, experimenting with 12 young women at Mount Holyoke College, found the energy expended in stair-climbing to be about fifteen times that required for walking the same distance on the level at the rate of about 2 or $2\frac{1}{2}$ miles per hour. These young women climbed a mountain stairway of 522 steps up the side of Mount Holyoke at a rate of about 80 steps a minute attached to a very simple type of respiration apparatus, so arranged that the weight of everything except the mouthpiece was supported by an operator who walked behind each subject. Figures 16 and 17 show other types of apparatus being used for the measurement of energy expenditure. The cost of descending the stairway was found to be only about one-third the cost of going up, or five times the cost of walking an equal horizontal distance.



(Courtesy of The New York Times)

Fig. 17. Using the Douglas Bag to Determine Energy Expended in Running

It is evident, then, that for practical purposes we need some way of expressing grades of activity, to indicate the relative severity of their demand upon the muscles. Atwater, in his experiments with the respiration calorimeter, used a stationary bicycle (ergometer) which could be adjusted to work against different degrees of electrical resistance; and with this he was able to compute the mechanical work actually done by his subjects, as well as their heat production, oxygen consumption, and carbon dioxide output. Atwater thus describes one

of his early experiments to determine the influence of work:

"In the rest experiment the subject was as quiet as he well could be. In the four days of the preliminary period he moved about but little and engaged in no considerable amount of either muscular or mental labor. During the four days passed in the chamber he was likewise quiet. The only muscular work done was that involved in dressing, putting up and taking down the folding chair, table, and bed, weighing himself and the absorbers, taking his meals, and caring for the excreta. He passed a large part of the time in reading and sleeping.

"In the work experiment the subject was engaged in active muscular labor. The energy of the external muscular work done was entirely transformed into heat within the chamber. The larger part was first transformed into electrical energy by a small dynamo which was belted to the wheel of a stationary bicycle, and was then transformed into heat by an electric lamp through which the current passed. A small portion was converted into heat by the friction of this bicycle dynamo or ergometer. The heat thus produced was measured with the heat given off from the body."¹

The following table shows the resulting figures.

	<i>Day</i>	<i>Calories</i>
Rest experiment:	1	2,348
	2	2,263
	3	2,302
	4	2,326
	<i>Average</i>	<u>2,310</u>
Work experiment:	1	4,060
	2	3,788
	3	3,833
	4	3,639
	<i>Average</i>	<u>3,830</u>
Calories representing work		<u>1,520</u>

With a bicycle ergometer (see Fig. 18), Benedict and Carpenter later (1917) studied the work done by a professional bicycle rider. In a "ride" of four hours and twenty-two minutes he accomplished a "century run" (or over 100 miles), expending on the average 9.75

¹ Atwater, W. O., and Rosa, B. B. *Description of a New Respiration Calorimeter and Experiments on the Conservation of Energy in the Human Body*, page 76. Office of Experiment Stations, Bulletin No. 63, U. S. Department of Agriculture (1899).

calories per minute (585 per hour), which was two and one-half times as much as when simply sitting on the bicycle and revolving the freely moving wheel. Another sustained effort even greater than this is recorded by Robinson, manager of the Pike's Peak Hotel and long accustomed to mountain climbing, who in two hours and thirty-one minutes ascended Pike's Peak from Manitou, 8.9 miles, the difference in altitude being 7,485 feet. His estimated energy expenditure was about 12.8 calories per minute (767 per hour).

For short periods, still more amazing feats of energy transformation have been accomplished by the human engine. By severe muscular work the energy output may be increased ten times in two minutes. A study of the maximum physical power of highly trained athletes was made by Henderson and Haggard on the Yale University boat crew which won the Olympic championship at Paris in 1924. No exertion calls into play so large a proportion of the muscular tissue as rowing. The stroke, repeated thirty or more times a minute, begins "in extreme flexion of trunk and legs, with a powerful drive of the extensor muscles, the strongest chain of muscles in the body; it then passes rapidly to extreme extension, pulling throughout against the high resistance of the oar, and ends with a powerful flexion of the arms. From this position the

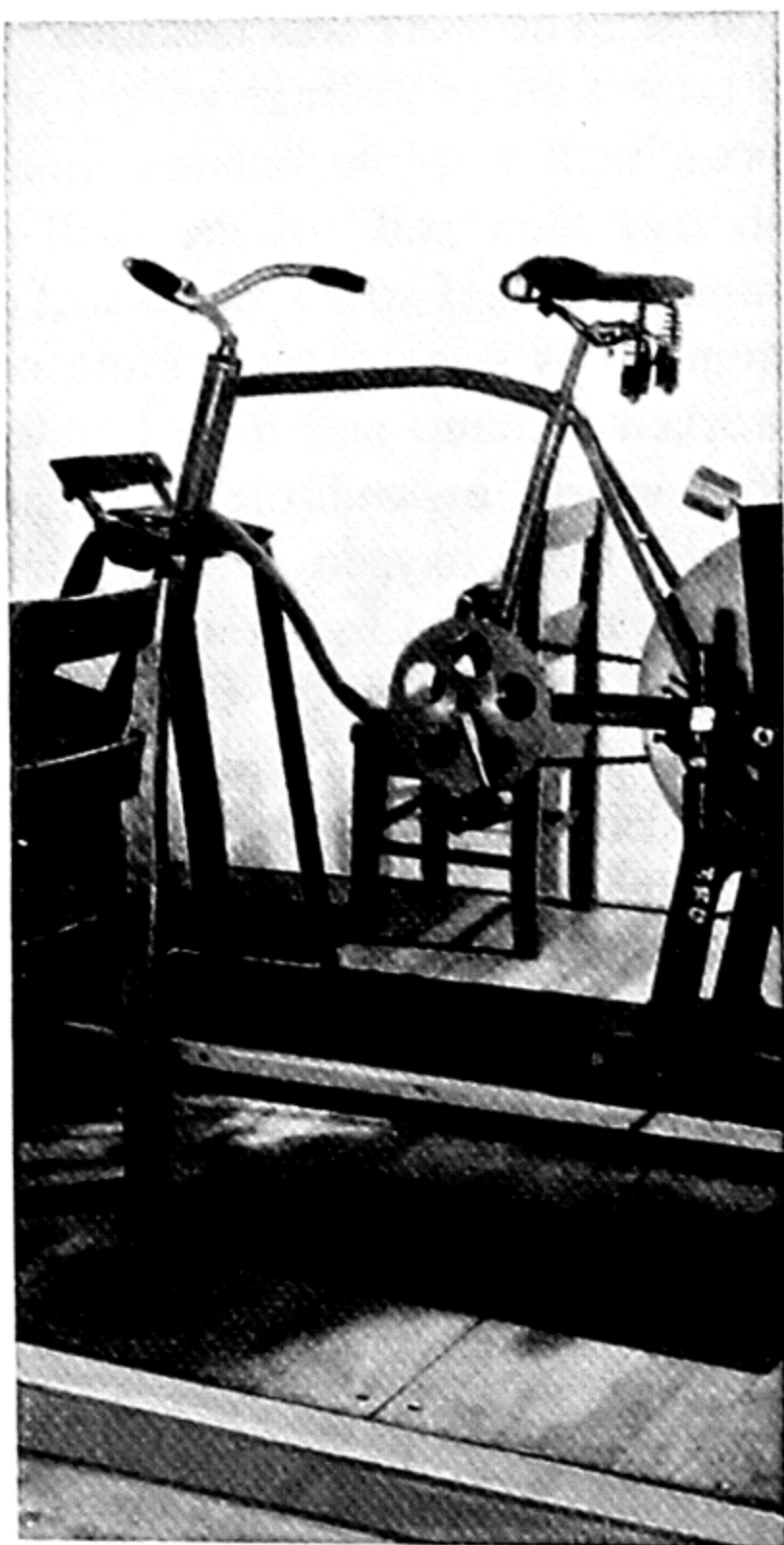


Fig. 18. The Bicycle Ergometer Used in the Nutrition Laboratory, Teachers College, Columbia University

A high-grade bicycle frame is mounted on a baseboard. In place of the rear wheel is a motorcycle hub fitted to a copper disk, and connected with this disk is an electromagnet. To increase the amount of work done the magnetic drag upon the disk is increased. The revolutions of the pedals are counted by means of a mechanical counter attached near the pedal-wheel hub.

recovery involves a rapid bending of the wrists, lowering the hands and shooting them forward, and a bending of ankles, knees, hips, waist and shoulders, with contraction of practically all the flexor muscles to these joints." The work was measured in three ways: (1) a racing shell with a crew with an average weight of 172 pounds was towed by a motor boat, with a spring balance attached to the launch and the towline so that the "pull" of the shell and crew could be weighed at the same time that speed was noted; (2) an oarsman "rowed" a certain number of strokes per minute on an apparatus in which the "oar" worked a pump and forced water against a resistance; and (3) the total energy expenditure of a man on the rowing machine was determined from oxygen consumption and carbon dioxide output. The energy expended by the men, who weighed from 154 to 185 pounds, ranged from 19 to 30 calories per minute (at the rate of 1,140 to 1,800 per hour). The lower figure represents the maximum which a man can maintain for twenty-two minutes during a four-mile race; the higher, for about six minutes in races of about one and one-third miles. The energy expenditure of the oarsmen in action was thus thirteen to twenty times the basal metabolism.

The foregoing are but a few striking examples of experiments to determine the energy expenditure during muscular work, in which nutrition literature abounds. Figure 19 shows how even changes of posture and light muscular effort quite definitely increase the energy output.

The Saving of Energy in Sleep

The true basal metabolism of an adult represents a condition of complete muscular repose with the brain active. What happens when the person is in complete muscular repose and at the same time asleep? One investigator so completely mastered the art of assuming at will a state of complete muscular relaxation that no difference was found between his basal and his sleeping metabolism. It is possible, however, that another person, who has achieved the greatest voluntary muscular relaxation of which he is capable, may exhibit a basal metabolism somewhat above the sleeping level because such influences as light and sound can act reflexively to increase the tonus of the muscles. This is well illustrated by Benedict's observations on Levanzin, the man who fasted in his laboratory 31 days. The investigator says: "A study of prolonged fasting recently carried out in this

laboratory afforded an excellent opportunity for comparing the metabolism during the night when the subject was sleeping quietly in the bed calorimeter with that of the next morning when he was lying quietly upon the same bed, awake and breathing into the universal respiration apparatus. The subject slept for the greater part of the period of observation in the bed calorimeter, the graphic record of

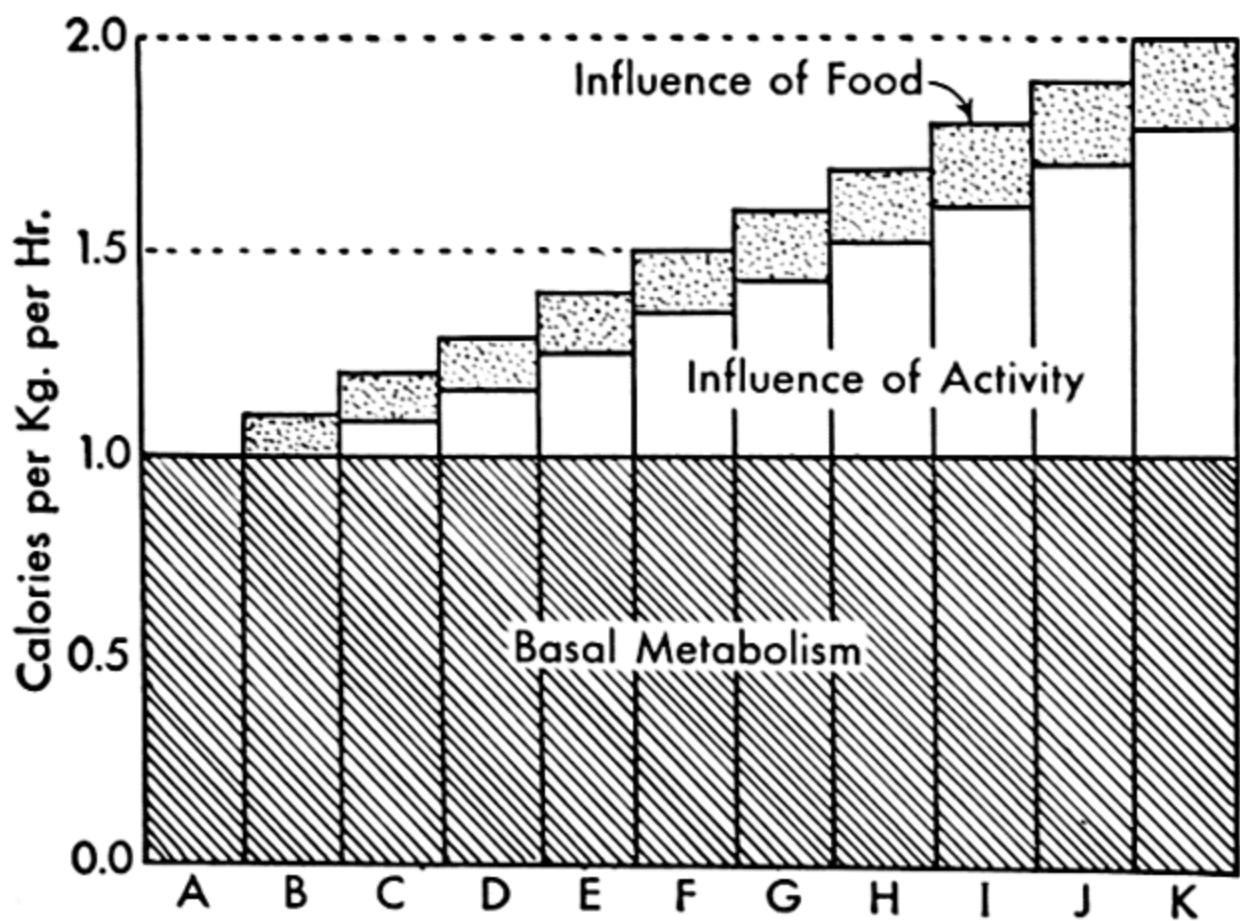


Fig. 19. Changes in Energy Output Due to Increasing Muscular Activity

State of Activity	Calories per Kg. per Hr. ^a
A. Lying absolutely still, no food taken (basal metabolism)	1.0
B. Lying absolutely still, food taken	1.1
C. Sitting in bed, absolutely still	1.2
D. Sitting quietly in bed, reading	1.3
E. Sitting at ease	1.4
F. Standing relaxed	1.5
G. Standing "at attention"	1.6
H. Dressing	1.7
I. Singing	1.8
J. Tailoring	1.9
K. Walking very slowly (about 1 mile per hour)	2.0

^a These figures include the basal metabolism.

the body movements made by the self-recording bed showing that the man was remarkably quiet throughout the whole night. During the morning observation, he was phenomenally quiet, the graphic record showing a practically straight line in every experiment. According to the opinion of Dr. T. M. Carpenter, who made the

observations with the respiration apparatus, the subject had the most complete muscular relaxation and control of any of the individuals that he had ever studied.”²

The metabolism of the subject while in the bed calorimeter during the night was compared with his metabolism immediately afterward when he was connected with the respiration apparatus in the morning, and it was always higher after waking, the increases varying from 4.5 to 27 per cent.

The same investigators compared the metabolism of a number of men when lying awake in the forenoon, covered with a blanket on a cot, with that of the period from 1 A.M. to 7 A.M. when the subjects were in the same position but asleep.³ The best three experiments showed an increase during the lying awake period amounting to about 11 per cent. Frequent observations of the pulse rate in the two conditions showed a decreased heartbeat and respiration rate during sleep, corresponding with the lower metabolic rate.

Every one realizes that sleep is not equally profound at all times, and that during sleep there may be muscular movements which would be suppressed were one awake and having his basal metabolism determined. This tendency to slight muscular movements may well account for some of the variations in sleeping periods, even with the same subject. Furthermore, what one has been doing previous to falling asleep may have some influence. In many of the experiments of Benedict and Carpenter with the respiration calorimeter at Wesleyan University the night periods were preceded by day periods in which the muscular activity varied greatly, and there was a tendency for the heat output to be greater on nights following work upon the bicycle ergometer than on nights following days of rest. Thus two subjects after moderate exercise showed a sleeping metabolism 7 to 8 per cent higher than their sleeping metabolism after rest, and one after severe exercise showed a metabolism 20 per cent higher. It is customary to allow for sleeping after moderate activity a saving of about 10 per cent of the basal metabolism, or 0.1 calorie per kilogram per hour.

² Benedict, F. G. "Factors Affecting Basal Metabolism." *Journal of Biological Chemistry*, Vol. 20, page 287 (1915).

³ Benedict, F. G., and Carpenter, T. M. *Metabolism and Energy Transformations of Healthy Man during Rest*. Carnegie Institution of Washington, Publication No. 126 (1910).

Section 3. ESTIMATING THE TOTAL ENERGY REQUIREMENT

We now have data from which we can estimate the energy requirement of a given individual with sufficient accuracy for most dietary purposes. Let us take Miss A., a college student, weighing 123 pounds, or 56 kilograms. Her daily schedule will not include much muscular activity, as much of her time will be spent sitting in classes or in reading in the library or perhaps in writing. By keeping a diary of her activities through the day, a table can be made giving the total time for each activity. Thus, dressing in the morning will take perhaps half an hour; changing for an afternoon tea, twenty minutes; and undressing and an unhurried bath at night, fifty-five minutes. All the time spent in dressing and undressing, therefore, amounts to one and three-fourths hours. Time for other activities is estimated in the same way.

By using such factors as are shown in the following table for each kind of activity the cost of all the activities of the day can be calculated. By adding to this cost the calories of the basal metabolism minus the calories saved in sleep and then 10 per cent of this total for the influence of food, we shall arrive at a satisfactory estimation of the total calorie requirement for the day. It is thus clear that the

THE ENERGY COST OF ACTIVITIES

(Exclusive of Basal Metabolism and Influence of Food)

Activity	Cal. per Kg. per Hr.	Activity	Cal. per Kg. per Hr.
Bicycling (century run)	7.6	Piano playing (Beethoven's	
Bicycling (moderate speed)	2.5	<i>Appassionata</i>)	1.4
Bookbinding	0.8	Piano playing (Liszt's	
Boxing	11.4	<i>Tarantella</i>)	2.0
Carpentry (heavy)	2.3	Reading aloud	0.4
Cello playing	1.3	Rowing in race	16.0
Crocheting	0.4	Running	7.0
Dancing, foxtrot	3.8	Sawing wood	5.7
Dancing, waltz	3.0	Sewing, hand	0.4
Dishwashing	1.0	Sewing, foot driven machine	0.6
Dressing and undressing	0.7	Sewing, motor driven machine	0.4
Driving automobile	0.9	Shoemaking	1.0
Eating	0.4	Singing in loud voice	0.8

(Continued on p. 54)

(Continued on p. 54)

THE ENERGY COST OF ACTIVITIES (Cont.)

Activity	Cal. per Kg. per Hr.	Activity	Cal. per Kg. per Hr.
Exercise		Sitting quietly	0.4
Very light	0.9	Skating	3.5
Light	1.4	Standing at attention	0.6
Moderate	3.1	Standing relaxed	0.5
Severe	5.4	Stone masonry	4.7
Very severe	7.6	Sweeping with broom, bare	
Fencing	7.3	floor	1.4
Horseback riding, walk	1.4	Sweeping with carpet sweeper	1.6
Horseback riding, trot	4.3	Sweeping with vacuum sweeper	2.7
Horseback riding, gallop	6.7	Swimming (2 mi. per hr.)	7.9
Ironing (5 lb. iron)	1.0	Tailoring	0.9
Knitting sweater	0.7	Typewriting rapidly	1.0
Laundry, light	1.3	Violin playing	0.6
Lying still, awake	0.1	Walking (3 mi. per hr.)	2.0
Organ playing ($\frac{1}{2}$ hand work)	1.5	Walking rapidly (4 mi. per hr.)	3.4
Painting furniture	1.5	Walking at high speed (5.3 mi.	
Paring potatoes	0.6	per hr.)	8.3
Playing ping pong	4.4	Walking down stairs	^a
Piano playing (Mendelssohn's		Walking up stairs	^b
<i>Songs without Words</i>)	0.8	Washing floors	1.2
		Writing	0.4

^a Allow 0.012 calorie per kilogram for an ordinary staircase with 15 steps, without regard to time.

^b Allow 0.036 calorie per kilogram for an ordinary staircase with 15 steps, without regard to time.

total energy requirement of the adult is made up of three quotas: (1) the calories for the basal metabolism, (2) the calories for activities, and (3) the calories for the influence of food. An example of such an estimation of the total energy requirement for one day, using the factors listed, is given below.

THE ENERGY REQUIREMENT OF ADULTS

Estimate of Calories for Activities for One Day

I	II	III	IV
Activity	Time, Hrs.	Factor (Cal. per Kg. per Hr.)	Cal. per Kg. II \times III
Lying still, awake	0.50	0.1	0.05
Sitting	1.25	0.4	0.50
Standing relaxed	0.75	0.5	0.38
Sitting, writing, or eating	8.00	0.4	3.20
Standing at attention	0.25	0.6	0.15
Dressing and undressing	1.75	0.7	1.23
Light exercise	1.00	1.4	1.40

THE ENERGY REQUIREMENT OF ADULTS (Cont.)

I	II	III	IV
Activity	Time, Hrs.	Factor (Cal. per Kg. per Hr.)	Cal. per Kg. II × III
Walking (3 mi. per hr.)	1.00	2.0	2.00
Dancing	1.00	3.8	3.80
Skating	1.00	3.5	3.50
Walking up stairs (4 flights)		0.036	0.14
Walking down stairs (4 flights)		0.012	0.05
	16.50		16.40

Body weight, 56 kg.
Total calories for activities per kg. (sum of column iv), 16.40 cal.
Total cost of activities (56 × 16.40 cal.), 918 cal.

Total for Day

	Calories
Basal metabolism for 24 hours	1,297 *
Saving in sleep, to be deducted	42 *
Corrected basal metabolism	1,255
Cost of day's activities	918
Total cost of metabolism	2,173
Influence of food (10 per cent)	217
Day's requirement	2,390

* To calculate basal metabolism:
Wt. 56 kg. (123 lb.); Ht. 157 cm. (62 in.); Surface area 1.57 sq.m.
826 cal. per sq.m. per day (see p. 34) × 1.57 sq.m. = 1,297 cal.
Saving in sleeping 7.5 hrs. (0.1 × 56 kg. × 7.5 = 42 cal.).

Estimation of the Total Energy Requirement
by a Short Method

To estimate the energy cost of activities by a short method, attention is called to the tabulation on page 56 in which activities for various types of days are described and the corresponding calories per kilogram per hour and per pound per hour given. The first step is to select the type of activity which most closely corresponds to that of your most typical days.⁴ For example, suppose you select type C with an allowance of 0.8 calorie per kilogram per hour. If

⁴ In selecting the type of day, if your day does not seem to be like any one of those described, estimate a factor between two of those given.

you weigh 56 kilograms, you multiply 0.8 by 56 and then by the number of active hours in the day which is obtained by subtracting sleeping time from 24 hours. If you sleep 7.5 hours your active hours would be $24 - 7.5$ or 16.5. The energy cost for the day's activities would then be $0.8 \times 56 \times 16.5$ or 739 calories.

To estimate the total calories for the day you then add together the following:

1. Calories for basal metabolism (corrected for saving in sleep, see pages 52 and 55)	1,255
2. Calories for activities	739
3. Calories for influence of food (10 per cent of the sum of the calories for basal metabolism and activities)	199
Estimated total calories for 24 hours	<hr/> 2,193

ESTIMATION OF CALORIES FOR ACTIVITIES FOR VARIOUS TYPES OF DAYS

<i>Type of Activity</i>	<i>Calories^a per Kg. per Hr.</i>	<i>Calories^a per Lb. per Hr.</i>
A. At rest most of day (Sitting, reading, etc., very little walking and standing)	0.5	0.23
B. Very light exercise (Sitting most of the day studying, with about two hours of walking and standing)	0.6	0.27
C. Light exercise (Sitting, typing, standing, laboratory work, walking, etc.)	0.8	0.36
D. Moderate exercise (Standing, walking, housework, gardening, carpentry, etc., little sitting)	1.1	0.50
E. Severe exercise (Standing, walking, skating, out- door games, dancing, etc., little sitting)	1.7	0.77
F. Very severe exercise (Sports as tennis, swimming, basketball, football, running, heavy work, etc., little sitting)	2.4	1.09

^a Exclusive of basal metabolism and the influence of food.

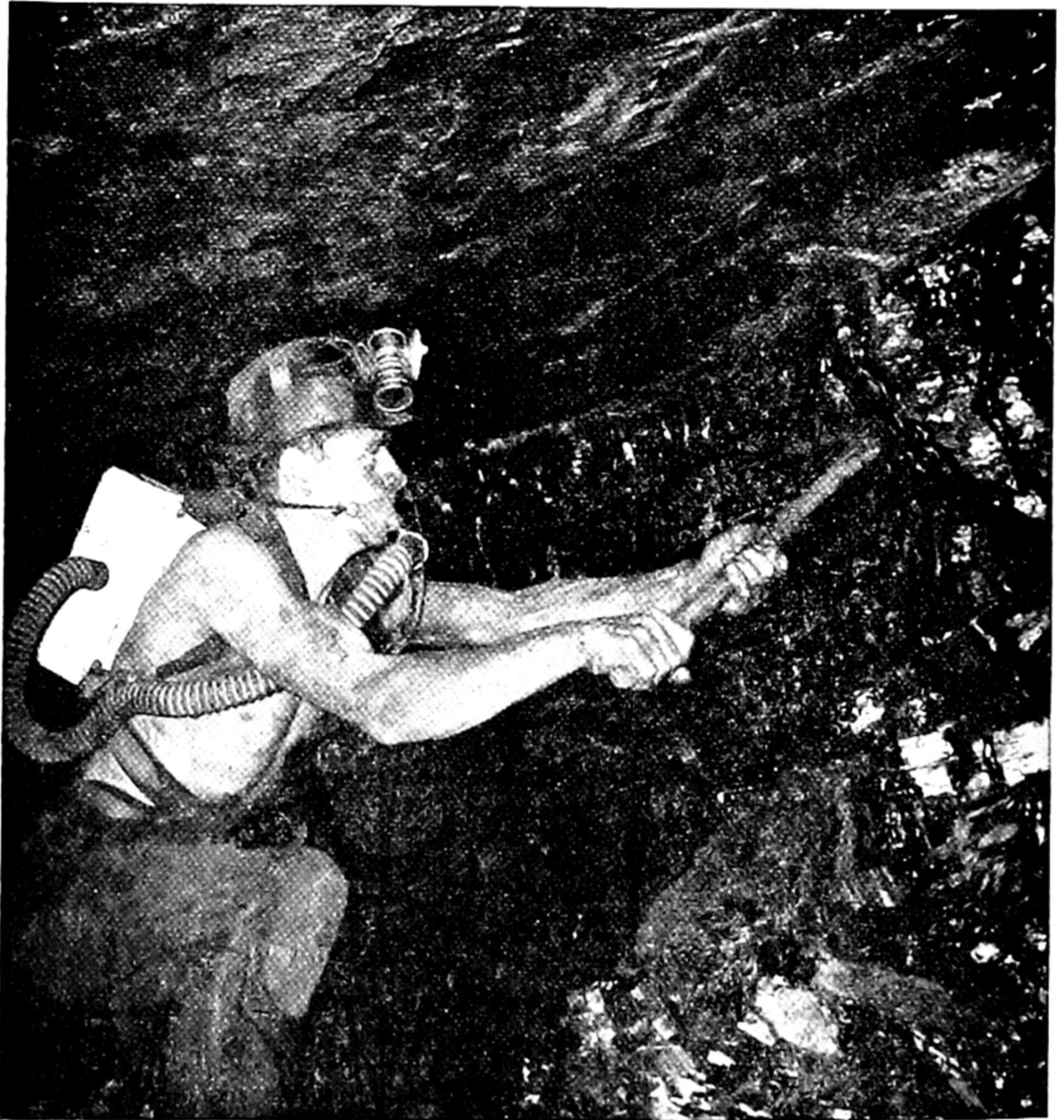
Total Energy Requirement According to Occupation

To compare the energy requirement per day of persons of different body weights it is necessary to find a common denominator of some sort. We may divide the total for the day by weight in kilograms and thus get calories per kilogram per day. Studies made by several hundred women students at Teachers College, Columbia University, of their energy expenditure for a typical school day enable one to predict that the students with lowest activity will need a total of about 33 calories per kilogram per day, while even the most active, being unable as students to escape a number of hours in the classroom, will seldom require more than 42 to 45 calories per kilogram. A man engaged for an eight-hour working day in such vigorous exercise as sawing wood will expend twice as much per kilogram per day as a quiet student. Extensive studies of the food consumption of various people indicate that those performing like amounts of work will have about the same average metabolism. Women at sedentary occupations, as milliners and stenographers, need about as much per day as quiet students, i.e., generally from 2,000 to 2,200 calories per day. Farmers, whether American, Mexican, Italian, or Finnish, require about 3,500 calories per day; United States soldiers in hard training, about 4,500 calories; and British cadets in training, 3,420 calories per day.

Lehmann, Müller, and Spitzer of the Max Planck Institute, Germany, using the Kofranyi-Michaelis apparatus, have made determinations of the energy expenditure of a large number of subjects at work on industrial jobs. Some of their results are as follows: printing plant jobs, 2,500 to 2,880 calories per day; for shoe repairing and shoe-making by hand, 2,970 to 3,140; locomotive engineers, 3,130 to 3,530; locomotive firemen, 3,450 to 4,670; railroad bed repairmen, 4,800 to 4,850; coal mining, 3,060 to 3,750; steel mill operations, 2,620 to 4,210; iron workers, 3,100 to 4,680. For three industrial jobs performed by women they report 2,460 to 2,730 for steel grinding, 2,720 for placing bricks on carts, and 2,940 for carrying tile.

Droese, Kofranyi, Kraut, and Wildemann, also of the Max Planck Institute and using the Kofranyi-Michaelis apparatus, have reported determinations of the energy expended by three housewives, each of whom did all her own housework. The study began with observations of the women doing their work in their own homes, each activity

of the day being accurately timed with a stop watch from the time of arising in the morning until they went to bed at night. The next step was the determination of the energy expenditure for each kind of activity listed. Multiplying the number of minutes spent during the day on each activity by the energy required per minute and adding these products gave the total energy expenditure for the work of the



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Fig. 20. Determining the Energy Expenditure in Coal Mining with the Kofranyi-Michaelis Apparatus

day. These totals for the three women were 3,070, 2,987, and 3,088 calories. These results are higher than those usually reported for housework. The difference, as suggested by the authors, may be due, at least in part, to the fact that the average body weight of the women

The Energy Requirement of Adults

was 76 kilograms and their working day 15 to 16 hours long, figures rather different from those for which results are usually given in the literature.

Passmore and his associates ⁵ at the University of Edinburgh have used the Kofranyi-Michaelis apparatus to measure the energy expenditure in various activities of five students, nineteen to twenty-five years of age. They obtained an average of approximately 2,900 calories per day when the boys were engaged in sedentary activities and approximately 4,700 calories per day when they were engaged in hard physical work. Garry and his associates ⁶ have used this apparatus to determine the energy expenditure of 19 underground miners and 10 clerks in a colliery in Fife, Scotland. Figure 20 shows one of the miners at work with the apparatus attached. The energy expenditure of these men for all their other activities of the 24-hour day was also determined in order to obtain the total daily energy expenditure. For the miners, this total averaged 3,660 calories; for the clerks, 2,800 calories.

For the man or the woman of average height and weight the total energy requirement for 24 hours will vary according to the type of occupation somewhat as follows:

DAILY ENERGY REQUIREMENT ACCORDING TO OCCUPATION

Type of Occupation	<u>Total Calories per Day</u>		Cal. per Kg. per Day
	Men	Women	
At rest but sitting most of day	2,000–2,200	1,600–1,800	30–33
Work chiefly done sitting	2,200–2,700	1,900–2,200	34–37
Work chiefly done standing or walking	2,800–3,000	2,300–2,500	38–42
Work developing muscular strength	3,100–3,500	2,600–3,000	43–50
Work requiring very strong muscles	4,000–6,000	—	55–70

Total Energy Requirement According to Age, Weight, and Activity

In Table III(b) in the Appendix will be found daily calorie allowances for men and women for three degrees of activity (“standard,” heavy, and sedentary) according to age and weight, based on the

⁵ Passmore, R., Thomson, J. G., and Warnock, G. M. “A Balance Sheet of the Estimation of Energy Intake and Energy Expenditure as Measured by Indirect Calorimetry, Using the Kofranyi-Michaelis Calorimeter.” *British Journal of Nutrition*, Vol. 6, page 253 (1952).

⁶ Garry, R. C., Passmore, R., Warnock, G. M., and Durnin, J. V. G. A. *Studies on Expenditure of Energy and Consumption of Food by Miners and Clerks, Fife, Scotland, 1952*. Medical Research Council, Special Report Series No. 289. Her Majesty’s Stationery Office (1955).

1953 recommendations of the Food and Nutrition Board of the National Research Council of the United States of America. This table gives calorie allowances for each decade of age from twenty-five to seventy-five years and for body weights ranging from 110 to 176 pounds (50 to 80 kilograms). It is suggested for use when it is not practical to make a detailed list of the day's activities.

"Standard" activity as used in this table is described by the Food and Nutrition Board as follows: "The basis of the recommendations is the calorie allowance for a 'standard' man and woman, both aged twenty-five, living in a temperate climate (mean annual external temperature 10° C.), and weighing 65 and 55 kilograms, respectively. These standard persons are presumed to be fairly active physically, being neither sedentary nor engaged in hard physical labor as a major occupation. The man could be employed in light industrial work; he could be a delivery man, a painter, an outdoor salesman, or a farmer except in the periods of heaviest farm work. The woman could be employed at bench work in a factory; she could be a shop saleswoman, or an active homemaker and mother. Both man and woman are presumed to engage in a moderate amount of outdoor recreation and to lead a vigorous healthy life. The allowances of 3,200 and 2,300 calories, respectively, appear to be satisfactory for this 'standard' man and 'standard' woman." The recommendations go on to suggest that the calories be reduced by approximately 5 per cent for each decade of age beyond twenty-five. For greater physical activity, which would be described as heavy work, it is suggested that an allowance of 20 to 25 per cent above the level for "standard" activity be made. For sedentary twenty-five-year-old men and women of standard size, lower limits of 2,500 and 1,800 calories are suggested. It is recommended that the lowest level of calorie allowance for extremely sedentary subjects and invalids who do not need to gain weight should be about 1.2 times the basal metabolism. These suggestions have been taken into consideration in working out the values given in Table III(b).

Influence of Climate on Total Energy Requirement

During World War II when the men of our armed forces had to live and fight in parts of the world ranging from tropical to arctic regions the question of the adequacy of the army rations, both as to quantity and quality, demanded careful attention. Johnson and Kark in 1947 reported results obtained on North American (United States

and Canadian) troops in surveys carried out for the United States Army between 1941 and 1946 in arctic and subarctic, temperate, desert, jungle, and mountain regions in North America, Europe, and Asia. The average day's food chosen by groups of 50 to 200 healthy, physically fit ground troops from the rations provided was carefully determined. The rations were furnished in ample amounts so that the men could have eaten more if they had wished to. The daily energy value of the food thus voluntarily consumed ranged from 3,100 calories in the desert (92° F.) to 4,900 calories in the arctic (—30° F.). The average values reported for the different climates are as follows: tropics, 3,200 and 3,400; temperate zone, 3,800; temperate mountain region (9,000 ft.), 3,900; arctic and subarctic regions, 4,400. The correlation between these average voluntary intakes and environmental temperature should be noted.

Another interesting report is that of Swain, Toth, and associates who studied the voluntary food consumption of garrison troops in the subarctic at Fort Churchill, Manitoba, Canada, during ten-day periods in November 1947 and February and April 1948. The average daily consumption, including purchases between meals at the canteen, was 5,620, 5,590, and 5,690 calories respectively, results somewhat higher than the 4,400 calories reported by Johnson and Kark for arctic and subarctic regions.

Still another report on requirements in cold climates was that of Rodahl who made surveys for weekly periods during the four seasons of the years 1950 and 1952 on a group of infantry soldiers and one of airmen on garrison duty at Ladd Air Force Base in Alaska and also of Eskimos in four different locations in Alaska. Members of the infantry and air force groups had lived in Alaska approximately a year at the time the study began. As in the two studies previously mentioned they were free to select their food in unlimited amounts. These amounts plus between-meal consumption gave an average daily calorie consumption per man of 2,950 in the air force group and 3,200 for the infantry men. Calorie expenditure was estimated from time-activity observations of the men and found to average 2,800 calories per man per day. From his studies Rodahl concluded that the average man engaged in similar activities in similar climatic regions would require approximately 3,000 to 3,500 calories per man per day at any season of the year. The studies of adult male Eskimos at four different locations in Alaska indicated that an average daily con-

sumption of approximately 3,100 calories sufficed to maintain body weight. The estimated average daily expenditure was approximately 2,700 calories.

The Food and Nutrition Board of the National Research Council recommends a 5 per cent increase in the calorie allowance for every 10° C. (18° F.) decrease in the average external temperature from 10° C. (50° F.); and a decrease of 5 per cent in the calorie allowance for every 10° C. (18° F.) increase in the average external temperature from 10° C. (50° F.). It is pointed out that although these adjustments are for application to differences in average *annual* temperature, they can be used for adjustment to seasonal differences as well. For example, in various parts of the United States the difference between average winter and summer temperatures may vary between 10° C. and 30° C. This would indicate corrections from 5 to 15 per cent in the energy allowances (increase in winter, decrease in summer) according to location. These adjustments assume an average amount of actual exposure to the climate. They would not be sufficient for persons spending most of their time out of doors and would be too great for those spending most of their time in heated buildings during the winter. For more details see *Recommended Dietary Allowances*, Revised 1953, National Academy of Sciences, National Research Council, Publication 302.

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The Energy Requirement of Children

Some Early Studies of Children's Energy Metabolism

So far we have been dealing with the energy needs of the healthy adult, whose basal metabolism varies but little from day to day or year to year, and whose total energy requirement is determined chiefly by size and muscular activity. We shall now consider the years from birth to maturity, in which age is the greatest single factor modifying energy needs.

The aphorism of Hippocrates, "Growing bodies have the most heat; they therefore require the most food," was based on accurate observation, but any quantitative measurements of the differences between the young and the adult were not forthcoming for twenty-three centuries. Fifty years after the death of Lavoisier, two other French investigators following in his footsteps conducted the first respiration experiments on children, using a copper mask attached to the child's face and collecting the expired air in large glass globes for subsequent analysis. Andral and Gavarret in 1843 thus studied 12 children between the ages of eight and sixteen years. About thirty years later (1877) the first observations on a baby's metabolism were made by Forster of Munich, whose work was inspired by that of Pettenkofer and Voit. He used a Pettenkofer-Voit respiration chamber just large enough to hold a child's cot and studied a number of children varying in age from fourteen days to thirteen years. In 1894, the first study of heat production during the initial week of life was made by Mensi of the Academy of Medicine in Turin, Italy. He placed the baby

under a large glass bell in which the oxygen was replenished and measured as the infant used it up, and the carbon dioxide exhaled was absorbed and weighed.

At almost the same time (1895), in Stockholm, Sonden and Tigerstedt, who had constructed a very large respiration chamber to study the problem of ventilation of school buildings, took various groups of children between eight and fifteen years of age, sometimes boys, sometimes girls, who were induced by reading or eating apples (occasionally candy) to sit quietly for periods of four and a half hours, so that their carbon dioxide excretion might be determined. This was the first extensive study covering different ages of both sexes. A little later (1899) the first comprehensive study of the changes in the metabolism throughout the whole life cycle of the individual from childhood to old age was undertaken in Germany by Magnus-Levy and Falk. The children included 11 boys and 9 girls ranging in age from two and one-half to fourteen years. Although carried out 57 years ago, this study was made with such skill that it is comparable with our best modern work.

In these and other experiments extending over nearly three-quarters of a century, little attention was paid to keeping the subject in absolute repose or to controlling the influence of food; nevertheless, it was clearly established that the energy metabolism of the growing child is not only greater, weight for weight, than that of the adult, but that it varies markedly with the age of the child.

Section 1. THE BASAL METABOLISM

The Basal Metabolism of Infants

Any study of the basal metabolism of the human infant must be made during sleep and not more than three or four hours after a meal, because there is no way of keeping a baby perfectly quiet when awake or hungry. It is therefore impossible to make studies of the basal metabolism of infants on exactly the same basis as those of older children and adults. The food raises the metabolism, the sleep may lower it. Probably the actual figures obtained are somewhat higher than true basal values.

Among the outstanding studies on infants are those of Benedict and Talbot, who established a respiration laboratory at the Massachusetts

General Hospital and pursued the investigation of newborn infants, their subjects finally numbering 105, varying in age from forty-three minutes to eight days.¹ They measured the basal metabolism using a respiration chamber containing a wire crib supported at one end upon a spiral spring and at the other upon a knife edge, so that every movement of the child could be detected and recorded. In order to study children of various ages, they subsequently transferred their respiration apparatus to the New England Home for Little Wanderers, and in 1921 published a splendid survey of the basal metabolism which included, all told, 108 boys and 70 girls from birth to the age of fifteen years.²

During the first week of life the baby's basal metabolism, estimated on the basis of calories per square meter of body surface, is at least one-third lower than that of the adult and very much lower than that of older infants and children, averaging 20 to 24 calories per square meter per hour. This low heat production is attributable to the low muscle tonus of the newborn. A similar condition exists in the premature infant, whose heat production is still lower.

By the end of the first two weeks the sleeping metabolism of the baby will have risen to approximately adult level, but it does not stop there; instead it keeps on rising rapidly until the end of the first year or early part of the second, when it reaches the highest point in the life of the individual. Thereafter, it declines, the rate varying with age until the adult level is reached, as shown in the tabulation on page 70.

The average infant at birth has about one-seventh the surface area of the adult man, but only one-twentieth his weight. Comparison of an actual study of an infant six months old, weighing 6.1 kilograms and having a surface area of 0.34 square meter, with an average adult having a surface area of 1.81 square meters will show the difference in results when the daily energy output is calculated both to surface and to weight.

¹ Benedict, F. G., and Talbot, F. B. *The Gaseous Metabolism of Infants with Special Reference to Its Relation to Pulse-rate and Muscular Activity*. Carnegie Institution of Washington, Publication No. 201 (1914). Also Benedict, F. G., and Talbot, F. B. *The Physiology of the New-born Infant; Character and Amount of the Katabolism*. Carnegie Institution of Washington, Publication No. 233 (1915).

² Benedict, F. G., and Talbot, F. B. *Metabolism and Growth from Birth to Puberty*. Carnegie Institution of Washington, Publication No. 302 (1921).

AN INFANT'S BASAL METABOLISM COMPARED WITH AN ADULT'S

	<i>Infant Calories</i>	<i>Adult Calories</i>
Total basal metabolism for 24 hours	312	1,700
Calories per square meter per hour	38.2	39.5
Calories per kilogram per hour	2.1	1.0

Here it appears, as already stated, that on the basis of surface this young child's metabolism is very close to that of the adult, but on the basis of body weight it is more than twice as great. As the child grows larger, the metabolism in terms of body weight as well as in terms of body surface gradually falls.

The Basal Metabolism of Children

The introduction of the Benedict portable respiration apparatus in 1918 greatly facilitated the study of the basal energy metabolism, its low cost making it available to many laboratories in which a respiration calorimeter would have been an unattainable luxury. At the University of Chicago, under the leadership of Dr. Katherine Blunt, studies with this apparatus were made on many children from the University Elementary School, one of the most important being on 96 normal children who came for their tests in the latter part of the morning instead of before breakfast, their parents having agreed to give them a light and early breakfast, with no meat, eggs, or coffee to cause any special stimulation of metabolism, and they having pledged themselves to eat nothing between this breakfast and the test. Preliminary experiments had shown that the effect of this small breakfast would be negligible after an interval of four hours.

In 1924, G. MacLeod³ reported tests on 43 girls from eleven to fourteen years of age from the Horace Mann School of Teachers College, Columbia University. The girls came without breakfast and after their test had a "breakfast party" in a kitchenette adjacent to the laboratory. Fifteen of these subjects were followed through two or three years. From this time on for a period of 20 years, Dr. MacLeod continued her active interest in the energy metabolism work with children, and under her leadership a number of studies of the basal metabolism and energy expenditure of children were carried out

³ MacLeod, G. "Studies of the Normal Basal Energy Requirement." *Dissertation*, Columbia University (1924).

in the Nutrition Laboratory of Teachers College, Columbia University, including those of Robb, Williams, Potgeiter, Taylor, Thompson, Lamb, and Robertson.

A study of the basal metabolism of the nursery school child by means of the Benedict respiration apparatus was reported in 1934 by Robb.⁴ Twenty-nine children (12 boys and 17 girls) three to four years of age were included. The children played with the mouthpiece and noseclip in the laboratory to become familiar with them. "A child was judged ready for a basal metabolism test when, during a preliminary play period, he would lie still with mouthpiece and noseclip adjusted, listening to a story for at least five minutes." During the test one adult sat by the child, telling him a story, while a second operated the apparatus. In studies of older children it has been found that nine-year-olds are mature enough not to need the services of two attendants during a test.

In cooperation with the Human Nutrition Research Branch, Agricultural Research Service, United States Department of Agriculture, an extensive study of the energy expenditure of children nine to eleven years of age has been under way since 1944 in the Nutrition Laboratory, Teachers College, Columbia University, under the direction of Taylor and Pye. Basal metabolism determinations have been made on 116 children (57 boys and 59 girls), repeated determinations having been made on a number of these children during a 2- to 3-year period.

Studies of the basal metabolism of normal healthy children have also been conducted in a number of other laboratories in the United States. Boothby, Berkson, and Dunn (1936) working at the Mayo Foundation; Lewis, Duval, and Iliff (1943) at the School of Medicine, University of Colorado; Lamb (1945) and Lamb and Michie (1954) at the Texas Technological College; Macy and her associates at the Research Laboratory, Children's Fund of Michigan; and others have published results of their studies of the basal metabolism of children varying in age from two years on through the period of growth up to fifteen to twenty years.

The interest in the basal metabolism of children has also extended to laboratories in other parts of the world. Nakagawa, working in Tokyo, Japan (1934), reported findings on 31 Japanese children

⁴ Robb, E. "The Energy Requirement of Normal Three- and Four-Year-Old Children." *Dissertation*, Columbia University (1934).

three years and ten months to six years and six months of age, and later, in 1937, he reported studies on high school children. Robertson and Reid (1952) studied English boys and girls three to twenty years old. In 1932, Wang and Hawks reported studies of the basal metabolism of 21 Chinese children reared or born and reared in the United States and ranging in age from five to eleven years.

Space does not permit the reporting of the detailed findings of all of this research. Although there are variations in the basal metabolism of children living in different locations, the final averages do not differ as much as one might anticipate. The reader is referred to the tabulation, made by the authors, on page 70, which will serve as a guide to the changes in the basal metabolism occurring from birth throughout the period of growth. It is commonly considered that a basal metabolism within plus or minus 10 to 15 per cent of the average figure for each age is normal unless other diagnostic findings indicate a pathological disturbance.

It will be observed that the basal metabolism increases rapidly during the first year, reaching a maximum between one and two years, thereafter falling rather rapidly for two or three years and then more gradually, until the onset of puberty. At this time there is a slight rise for a period of two or three years and then a gradual decrease to the adult level.

DuBois in 1916 determined the basal metabolism of 8 boy scouts twelve to fourteen years of age and found it to be 25 per cent above the adult level on the basis of surface area. Three of the boys showed no sign of approaching puberty, 5 gave more or less definite signs. Two years later (1918), when puberty was established in every case, the boys had an average increase in weight of 46 per cent and in height of 10 per cent, but the basal metabolism had dropped rather sharply and was, on the basis of surface area, 13 per cent less than before, but still about 11 per cent higher than the adult level.

In a group of 6 boys ten to sixteen years of age studied by Taylor and MacLeod⁵ over a period of six years, the basal metabolism of each boy being determined at intervals of six months, there seemed to be in each case two rather abrupt increases in the basal metabolism, one occurring at about twelve years, with a sharp drop thereafter,

⁵ Taylor, C. M., and MacLeod, G. "The Influence of Age on the Basal Metabolism of Boys throughout Six Consecutive Years." *Journal of Home Economics*, Vol. 32, page 561 (1940).

BASAL ENERGY METABOLISM OF CHILDREN FROM BIRTH TO EIGHTEEN YEARS

Age	<i>Calories per Square Meter per Hour</i>		<i>Calories per Kilogram per Hour</i>	
	Boys	Girls	Boys	Girls
Premature infants	25	25		
Birth to 2 weeks	26-29	26-29		
3 months	39	36	2.21	2.21
6 months	43	41	2.25	2.25
9 months	47	46	2.29	2.29
12 months	48	46	2.33	2.33
15 months	48	46		
18 months	48	46		
21 months	48	46		
2 years	48-54	45-53	2.29	2.29
3 years	47-53	43-51	2.13	2.00
4 years	46-52	41-50	1.96	1.83
5 years	45-51	42-49	1.88	1.75
6 years	44-53	41-50	1.79	1.67
7 years	43-53	40-52	1.71	1.63
8 years	42-52	40-47	1.67	1.58
9 years	42-50	40-46	1.58	1.54
10 years	41-48	37-46	1.54	1.50
11 years	39-48	38-45	1.46	1.42
12 years	39-51	38-44	1.42	1.33
13 years	39-49	37-43	1.67	1.29
14 years	38-46	37-43	1.71	1.54
15 years	41-46	31-43	1.50	1.33
16 years	41-45	31-40	1.38	1.25
17 years	41-44	31-40	1.25	1.17
18 years	41-43	32-38	1.25	1.08

and the second at about fourteen and one-half years. On the other hand, Webster ⁶ and his co-workers reported that they obtained no evidence of an increase in the basal metabolism at the time of puberty in a group of 13 boys and 8 girls between the ages of ten and sixteen years on whom basal metabolism determinations were made at intervals of four months over a period of five years.

In the study of 43 girls between eleven and fourteen years of age

⁶ Webster, B., Harrington, H., and Wright, L. M. "The Standard Metabolism of Adolescence." *Journal of Pediatrics*, Vol. 19, page 347 (1941).

made by MacLeod there was evidence of an increase in the basal metabolism at puberty corresponding to that found in boys by DuBois and by Taylor and MacLeod. In the study reported by Shock ⁷ (1943) of 50 normal girls on whom tests were made at intervals of six months beginning at eleven and one-half years of age and continuing for six years, the observations did not begin early enough to show a distinct premenstrual rise, but in each case a rapid fall in the basal metabolism occurred throughout the three years following the onset of menstruation. The basal oxygen consumption of those girls between twelve and fourteen years of age who had already passed the menarche was about 10 per cent lower than that of those who had not yet menstruated. When the results were averaged according to chronological age these changes were obscured due to the wide range of chronological ages at which individual girls mature.

Section 2. THE ENERGY REQUIREMENT FOR ACTIVITY

In the child, as in the adult, muscular activity increases energy expenditure in proportion to its severity. It is difficult, however, to standardize the activities of infants and children. Attention has already been called in Section 1 of this chapter to the studies of Benedict and Talbot on infants. They observed instances in which a baby's metabolism was raised as much as 200 per cent above the basal level by vigorous crying. However, few babies can cry as hard as that, and an average baby is not likely to exceed his basal output by more than 65 per cent and that for only a short time. Murlin has also studied infants and found the extra expenditure in crying proportional to the time spent and estimated that an allowance of 30 per cent would be sufficient for an average normal infant and 40 per cent for an infant crying "most of the time." Benedict and Talbot suggested an allowance of 25 per cent above the basal for young infants, and for older infants, not confined to the crib, an allowance of 30 to 40 per cent.

In 1922, Miss E. M. Bedale in a private school in Hampshire, England, measured the energy cost of 25 separate activities, 45 boys and 55 girls, eight to eighteen years of age, serving as subjects. For these measurements she used the Douglas bag (Fig. 17). The increases over the basal metabolism of some of the activities were as follows:

⁷ Shock, N. W. "The Effect of Menarche on Basal Physiological Functions in Girls." *American Journal of Physiology*, Vol. 139, page 233 (1943).

INCREASE OVER BASAL METABOLISM IN DIFFERENT ACTIVITIES

<i>Activities</i>	<i>Per Cent over Basal</i>
Piano practice	56
Standing	80
Dressing	170
Cricket	259
Gymnastics	298
Gardening	305
Cold bath	503
Dancing	547
Swimming	669
Football	762

For studies of energy expenditure under a variety of conditions, a respiration chamber is most accurate and convenient. With such a chamber, MacLeod and her associates have made a number of studies of the cost of activity in children. In the investigation with Robb (1934), already referred to, the first study of the energy output of nursery school children at quiet play was made by means of a respiration chamber. Three children were taken into the chamber at a time by an adult who remained with them, sitting quietly at one side, during a half-hour test period while the children played with blocks, trains, balls, tinker toys, etc. The energy expenditure of the adult was measured separately and deducted from the total.

In 1933, Potgieter⁸ reported a study on girls, nine and ten years old, during quiet play and when climbing up and down steps in the respiration chamber.

In 1937, the first studies of nine- to eleven-year-old boys using a bicycle ergometer in a respiration chamber (Fig. 21) were reported by Taylor.⁹ The energy expenditure of quiet play and cycling was measured. These studies were followed by similar studies on girls of the same age range by Thompson¹⁰ (1940). Robertson¹¹ (1942)

⁸ Potgieter, M. "The Energy Cost of Physical Activity of Nine-Year-Old Girls." *Dissertation*, Columbia University (1933).

⁹ Taylor, C. M. "The Energy Metabolism and Mechanical Efficiency of Young Boys." *Dissertation*, Columbia University (1937).

¹⁰ Thompson, E. M. "A Study of the Energy Expenditure and Mechanical Efficiency of Young Girls and Adult Women." *Dissertation*, Columbia University (1940).

¹¹ Robertson, M. E. "A Study of the Energy Metabolism and Mechanical Efficiency of Children Six to Eight Years of Age." *Dissertation*, Columbia University (1942).

studied boys and girls (six to eight years of age) performing similar activities, and Lamb ¹² (1942) reported studies on boys twelve to fifteen years of age. The children went into the chamber in pairs, one sitting at quiet play while the other pedaled the bicycle ergometer. Red and green lights helped the cyclist to maintain a constant speed, red flashing on when he went too fast and green when he went too slow.

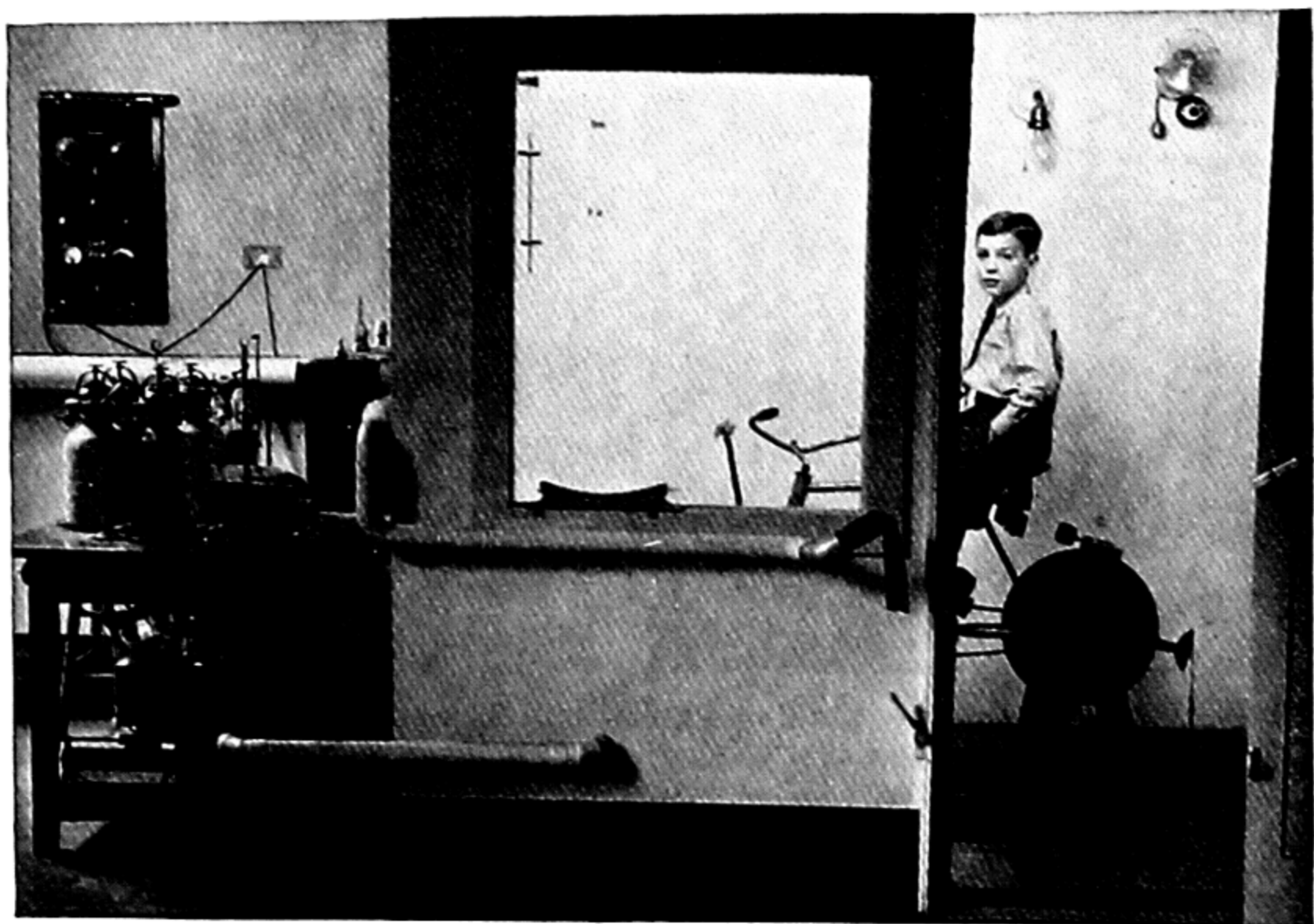


Fig. 21. The Respiration Chamber and Bicycle Ergometer, Nutrition Laboratory, Teachers College, Columbia University

The most extensive of the studies of energy expenditure of children of any one age group is that which has been conducted by Taylor, Pye, and associates in the Nutrition Laboratory of Teachers College in cooperation with the Human Nutrition Research Branch, Agricultural Research Service, United States Department of Agriculture. Since 1944, when the study was started, the energy expenditure of boys and girls between nine and eleven years of age has been measured for more than 25 different activities. Many types of apparatus have

¹² Lamb, M. M. W. "A Comparison of the Energy Expenditure and Mechanical Efficiency of Boys and Young Men and Some Observations upon the Influence of Age and Work Done on the Mechanical Efficiency of Boys." *Dissertation*, Columbia University (1942).

been used for these studies, including the respiration chamber (Fig. 22), Douglas bag (Fig. 17), Benedict's knapsack apparatus (Fig. 23), and his field respiration apparatus (Fig. 24), the apparatus se-

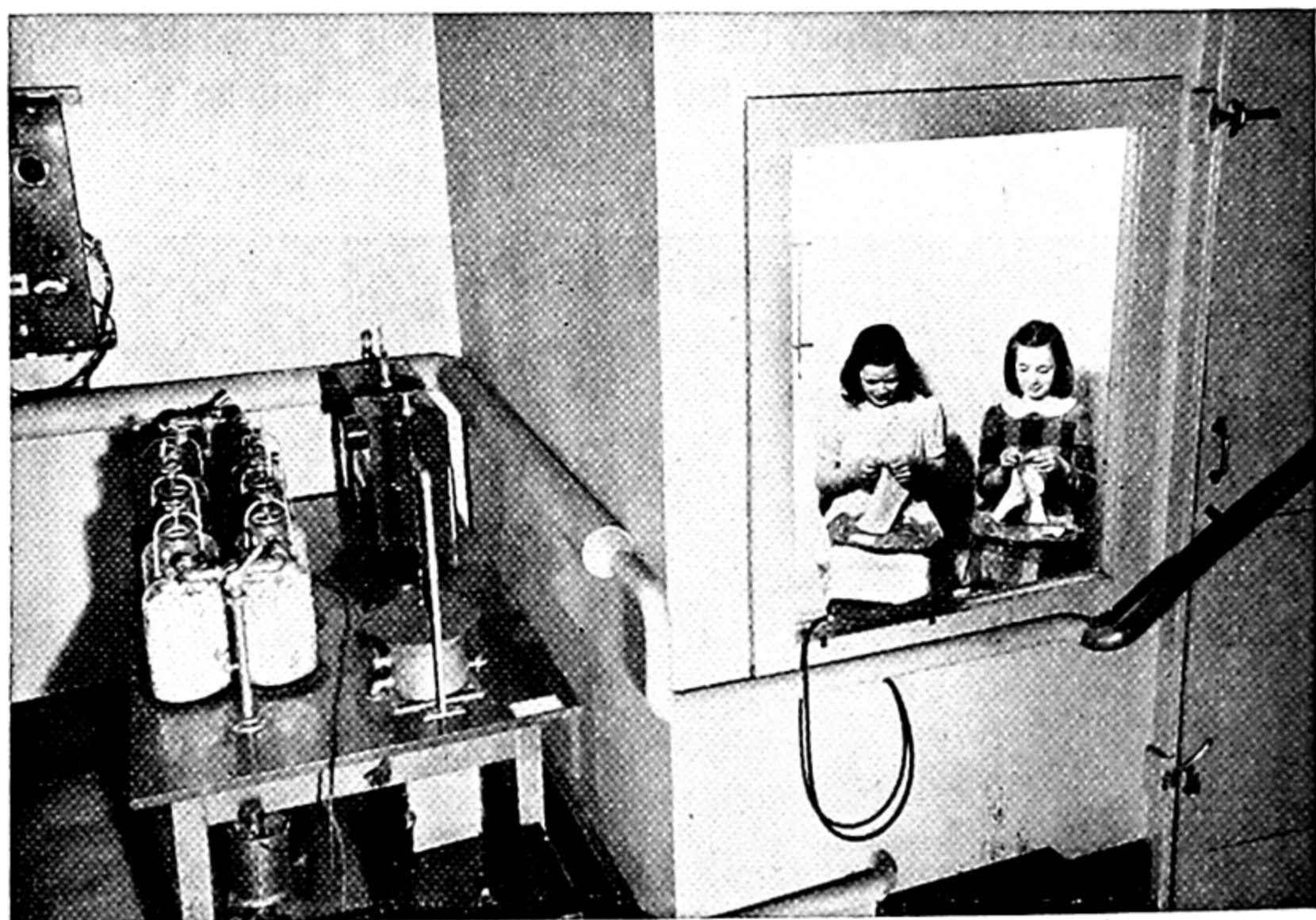


Fig. 22. Using the Respiration Chamber to Measure the Energy Expenditure in Sewing in the Nutrition Laboratory, Teachers College, Columbia University

lected being that best suited for the study of the particular activity. Preliminary surveys of the activities of children of this age group living in different situations (cities, suburbs, rural areas, at home, and in institutions) were made. These surveys gave a good idea of how many different types of activities the nine- to eleven-year-olds engaged in and which activities needed to be studied in order to obtain a better idea of the energy expenditure of children of this age range. These studies are in the process of being summarized for publication at the present time. The results of the studies of activities already published are listed in the tabulation on page 75.

These studies indicate quite clearly that the younger the child the greater is the energy expenditure per unit of weight in any given type of activity. Thus, sitting quietly playing games in the case of a nursery school boy resulted in an output of 1.62 calories per kilogram per hour above the basal metabolism; for the six- to eight-year-old

ENERGY EXPENDITURE FOR ACTIVITIES COMPARED WITH THE
BASAL METABOLISM ^a

Activity	Age, Years	Basal Metabolism Calories per Kg. per Hr.		Cost of the Activities above the Basal Metabolism Calories per Kg. per Hr.	
		Boys	Girls	Boys	Girls
Sitting quietly					
playing games	3-4	2.36	2.19	1.62	1.43
Cycling	6-8	1.91	1.81	4.47	4.38
Sitting quietly					
playing games	6-8	1.91	1.81	1.05	0.99
Carpentry (light)	9-11	1.51 ^b	—	2.07	—
Climbing up and down steps	9-11	—	1.47 ^b	—	4.65
Cycling	9-11	1.51	1.47	3.61	3.46
Dressing and undressing	9-11	1.51	1.47	2.74	2.66
Sitting drawing	9-11	1.51	1.47	0.75	0.64
Sitting listening to the "radio"	9-11	1.51	1.47	0.56	0.33
Sitting sewing	9-11	—	1.47	—	0.38
Sitting singing	9-11	1.51	1.47	0.72	0.59
Sitting quietly					
playing games	9-11	1.51	1.47	0.96	0.94
Standing drawing	9-11	1.51	1.47	1.68	1.13
Standing singing	9-11	1.51	1.47	0.84	0.66
Washing and wiping dishes	9-11	1.51	1.47	1.41	1.14
Cycling	12-15	1.31	1.21	3.19	2.10
Sitting quietly					
playing games	12-15	1.31	1.21	0.67	0.64

^a Results of studies carried out in the Nutrition Laboratory, Teachers College, Columbia University.

^b Average basal metabolism of all subjects nine to eleven years of age.

boy 1.05 calories; for the nine- to eleven-year-old, 0.96 calorie; and for the twelve- to fifteen-year-old boy, 0.67 calorie per kilogram per hour. In all cases the boys have a higher energy expenditure than the girls per unit of body weight and both boys and girls have a higher energy expenditure than adults performing similar activities (see Fig. 25 for comparisons).

Section 3. OTHER FACTORS INFLUENCING THE ENERGY REQUIREMENT OF CHILDREN

The Influence of Food

We have seen, in studying the energy requirements of adults, that an allowance must be made for the influence of food (specific dynamic action). This varies with the nature of the diet, but is not likely in ordinary life to exceed 10 per cent of the calories for basal metabolism plus activity. We have as yet very little exact information in regard to the stimulating influence on metabolism of food during growth, but we know that food which is stored in the process does not stimulate metabolism.

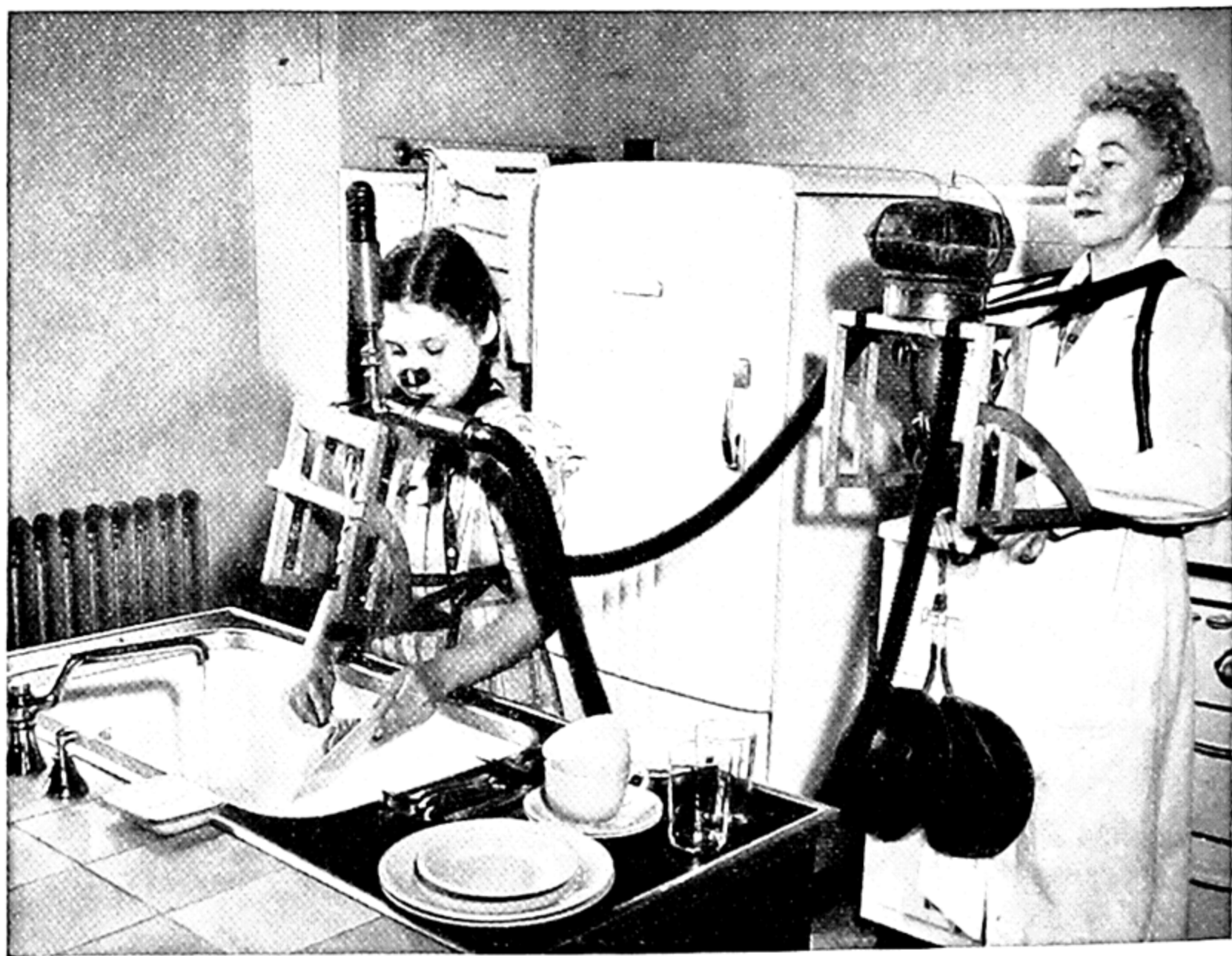


Fig. 23. Determining the Energy Expenditure for Washing Dishes with the Benedict Knapsack Apparatus in the Nutrition Laboratory, Teachers College, Columbia University

The Influence of Growth

The proportion of the total calories ingested which will be used for growth will vary directly with the rates of growth. The charts

in Section 2, Chapter 28, showing the average annual gain from birth to the age of eighteen years for both boys and girls, will serve to make clear that the periods of greatest storage in growth occur in the first year of life and again between the ages of twelve and sixteen,

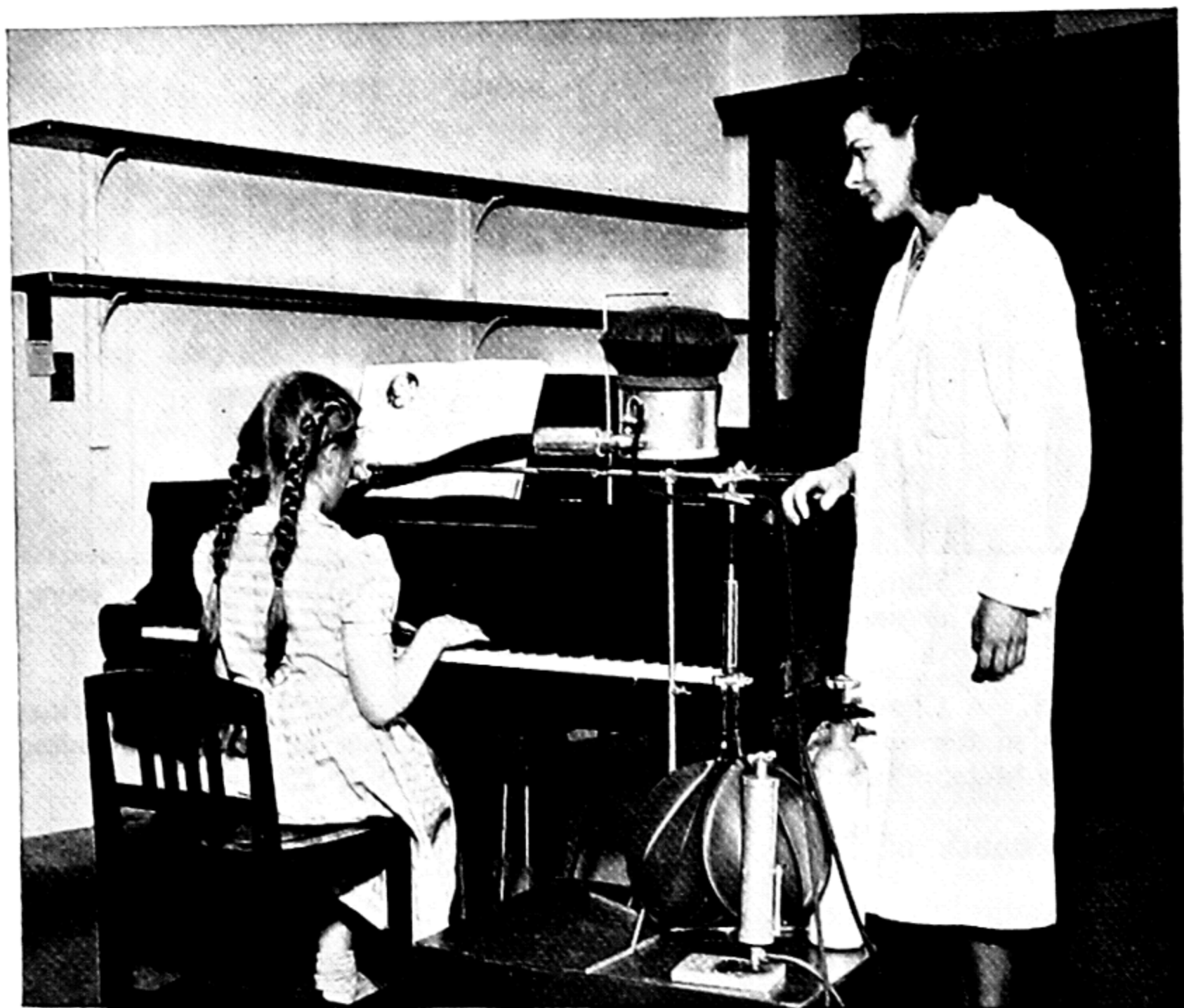


Fig. 24. Using the Benedict Field Respiration Apparatus to Measure the Energy Expended in Piano Playing in the Nutrition Laboratory, Teachers College, Columbia University

the fourteenth year in boys and the twelfth year in girls generally being the time when the rapid growth of adolescence reaches its maximum. In any one of these years from 10 to 15 pounds may be added to the body weight.

Just how many calories are needed for growth at any given time it will always be difficult to say, since the rate of growth varies considerably with the individual; at the present time we have no standard figures for the growth quota, but with the exception of the periods of most rapid growth, 10 to 15 per cent of the basal metabolism probably represents the growth requirement fairly well. It must be con-

stantly borne in mind that storage in growth is only possible when the basal energy requirement, the influence of food, and the additional calories needed for activity have been met. If there are no calories in excess of these requirements, there can be no growth.

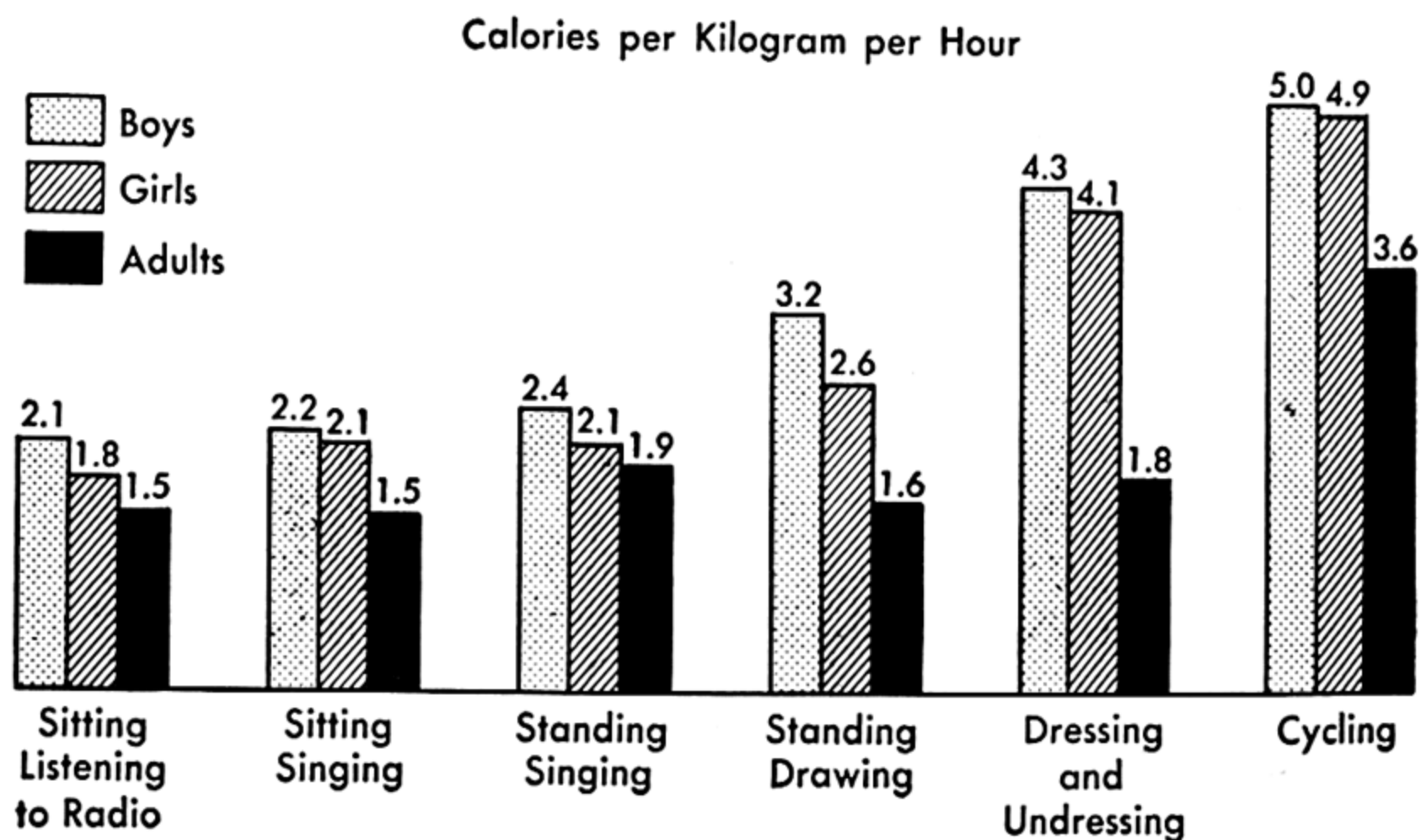


Fig. 25. A Comparison of the Energy Expenditure for Different Activities by Nine- to Eleven-Year-Old Boys and Girls with that of Adults (Including the Basal Metabolism)

The Influence of Sleep

The complete relaxation of a healthy sleeping child is always impressive, and indicates a decrease in the energy expenditure below the basal metabolism. The amount of this reduction can be determined only by careful testing. Benedict in 1922 studied two newborn babies in the respiration chamber and found their sleeping metabolism 6 and 15 per cent lower than their basal metabolism. A few years later Dr. Chi Che Wang and Miss Ruth Kern studied five boys and seven girls between the ages of four and seven years in the same type of chamber at the Michael Reese Hospital in Chicago. The average saving in sleep was 16 per cent. In the same year Wilson, Levine, and Rivkin reported the results of a study of five children, seven to nine years of age. They found a saving in sleep of 11 to 27 per cent. In 1934 Williams¹³ determined the sleeping metabolism of four nursery school

¹³ Williams, D. E. "The Influence of Sleep on the Energy Metabolism of Three- and Four-Year-Old Children." *Dissertation*, Columbia University (1934).

children, two boys and two girls between three and four years of age, taking their midday nap in the respiration chamber at Teachers College, Columbia University, and then their energy output with the Benedict student apparatus immediately upon waking. The differences between the two ranged from 12 to 23 per cent, showing the great relaxation in the first hour of sleep after a morning of active exercise in the nursery school. Comparing these results with the allowance usually made for saving in sleep by adults (10 per cent), it seems safe to assume that the energy saved in sleep by children may be in the neighborhood of 17 per cent.

Section 4. THE TOTAL ENERGY REQUIREMENT OF CHILDREN

We have now considered separately the four quotas which together constitute the total energy requirements of children, viz.,

1. Basal metabolism
2. Metabolism due to influence of activity
3. Metabolism due to influence of food
4. Storage of energy-yielding material in growth

The changes in the total daily requirement as influenced by each of these quotas are roughly indicated in Fig. 26.

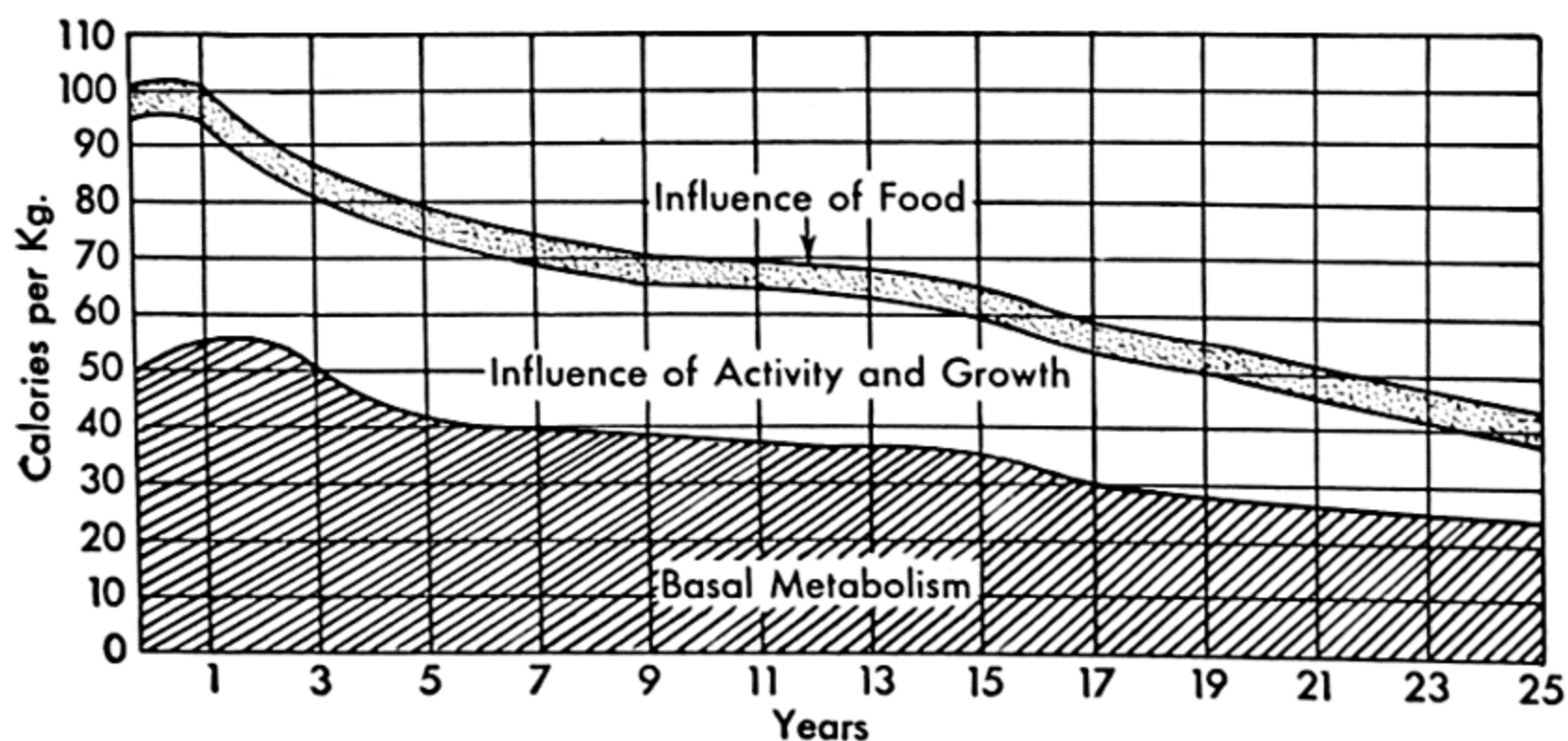


Fig. 26. Changes in Energy Requirements of Children with Age

Since basal metabolism and activity are relatively greater than in the adult and there is an additional requirement for growth, it is

plain that children's total food needs will be considerably higher than those of adults in proportion to body weight.

Much of our information as to the total energy requirement of children has come from studies of the actual food consumption of healthy children. In 1932, Dr. Lydia J. Roberts,¹⁴ of the University of Chicago, in her report to the White House Conference on Child Health and Protection, estimated from the available data the energy needs of the first year as follows:

TOTAL DAILY ENERGY NEEDS OF INFANTS
BY MONTHS

<i>Age, Months</i>	<i>Calories per Day</i>
1	500
2	610
3	675
4	720
5	760
6	795
7	820
8	860
9	880
10	900
11	940
12	1,000

In 1917 the New York Association for Improving the Condition of the Poor (now known as the Community Service Society), feeling the need in its extensive welfare work for adequate standards by which to compute the food requirement of the family, arranged for a systematic survey and digest of all the available data relating to food requirements of children. This was made by Miss Lucy Gillett, Director of Nutrition for the Association, and included 563 studies in all, covering the period from 1878 to 1917. From this were formulated the first American standards for total energy requirements of children.

The introduction of the oxy-calorimeter in 1925, described in the following chapter, facilitated a type of study most useful in learning children's total energy requirements. Accurate account of the food consumed over a sufficiently long period and careful records of the child's changes in weight are essential. The energy value of the food

¹⁴ White House Conference on Child Health and Protection. *Growth and Development of the Child*, Part III, "Nutrition," page 392. The Century Co. (1932).

can be determined by drying a whole meal or a whole day's ration and burning a sample in the oxy-calorimeter. If growth is normal, the calories eaten must have been sufficient to compensate for the energy expenditure and storage of energy-yielding materials in growth. Roberts and her students applied this method in a study of 35 boys doing farm work in comparison with 34 boys engaged in the ordinary activities of school life, and also in one of 52 girls from ten to sixteen years of age, mostly living in well-managed institutions.¹⁵ The method was also used in 1950 by the Human Nutrition Research Branch of the Agricultural Research Service of the United States Department of Agriculture for a study of the calorie value of school lunches.

An extended study of the food consumption of girls six to thirteen years old was conducted by Dr. Martha Koehne and Miss Elise Morell¹⁶ at University Hospital, Ann Arbor, Michigan. Quantitative records were kept for 28 girls, 11 of whom were under observation for from 91 to 192 days and only 3 for less than 40 days. The menus were standardized—one for each day of the week—to simplify work in the kitchens where all of the food was accurately measured or weighed. The portions eaten by each child were also weighed. The weight of first portions was always adjusted to the size and appetite of the child, but additional weighed portions were served on request. The children were weighed once a week and measured once a month and the nutritive value of each diet was calculated from average analyses. During the course of these investigations, 35 balance studies for periods of one week each furnished evidence that the estimations of food intake were reasonably accurate.

Gillett, in setting dietary standards for children, suggested that the total energy requirement is at least double the basal metabolism and this was confirmed by Dr. Chi Che Wang¹⁷ and her associates working under the Children's Hospital Research Foundation at the University of Cincinnati with regard to girls between twelve and fifteen years of age. Twenty-two of them lived for two weeks in the metabolism ward, going out to school and returning for meals and the night's

¹⁵ Wait, B., and Roberts, L. J. "Studies in the Food Requirement of Adolescent Girls. I. The Intake of Well Nourished Girls." *Journal of the American Dietetic Association*, Vol. 8, page 209 (1932).

¹⁶ Koehne, M., and Morell, E. "Food Requirement of Girls from Six to Thirteen Years of Age." *American Journal of Diseases of Children*, Vol. 47, page 548 (1934).

¹⁷ Wang, C. C., Kaucher, M., and Wing, M. "Metabolism of Adolescent Girls." *American Journal of Diseases of Children*, Vol. 51, page 801 (1936).

rest. Their food was weighed and samples analyzed. It was found that their basal metabolism accounted for fully half the total calories represented in their food. Such an allowance, while sufficient for children whose activities may be classed as light work, would not be sufficient for those who are more active. For boys, especially between eleven and fifteen years of age, an allowance of three times the basal metabolism seems desirable. Bedale found English school children, both boys and girls, spending about this amount.

Roberts collected all available data on the total energy requirement of children and plotted curves for both boys and girls which represent the average intake per day at different ages. These curves are reproduced in Fig. 27.

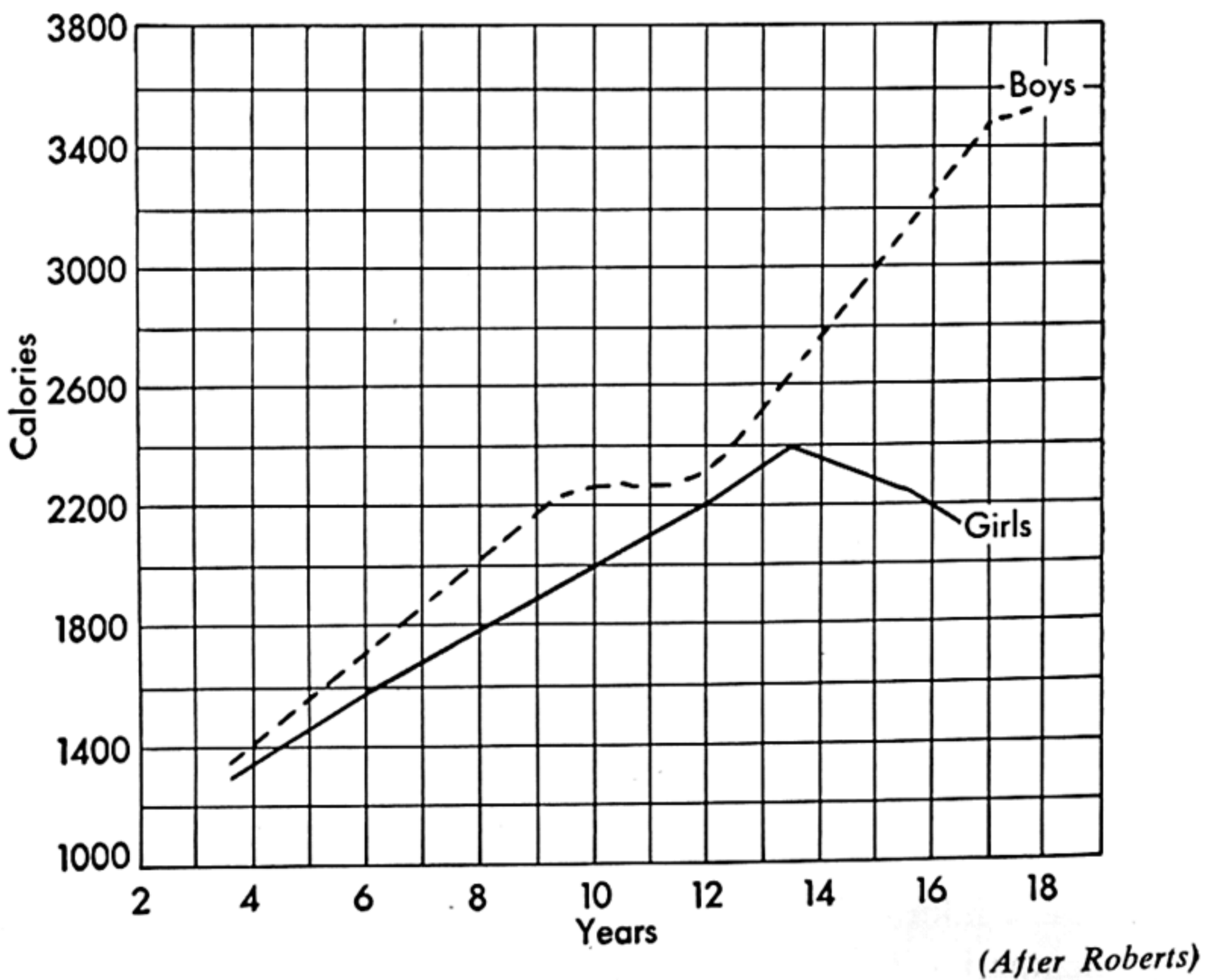


Fig. 27. Total Daily Energy Intake of Normal Boys and Girls

Changes in the feeding of boys are illustrated by the history of Christ's Hospital, the famous English school established by Edward VI in 1553. Records of the diet and the physical development of the boys have been made available by the Chief Medical Officer of the school.¹⁸

¹⁸ Friend, G. E. *The Schoolboy. A Study of His Nutrition, Physical Development and Health*. W. Heffer and Sons, Cambridge, England (1935).

The Energy Requirement of Children

An existing diet sheet for the week ending August 12, 1704, shows that the boys, nine to eighteen years old, received only 1,170 calories in solid food (mostly bread, with cheese and a little butter) and an estimated 730 calories in crude, home-brewed beer. Charles Lamb, who attended the school from 1782 to 1789, bears touching testimony in his *Essays of Elia* to the miserable quality as well as quantitative inadequacy of the dietary regime of that period when, as Drummond aptly says, "Food restriction in both quantity and quality was widely regarded as one of the disciplines to which the child was subjected for the good of its soul."¹⁹

Knowledge of the food requirements of mankind was greatly needed. The Governors of the school little knew how near the truth they came when they forbade vendors of any sort to sell "anything eatable or drinkable" to the schoolboys in saying, "This tends not only to the prejudice of the children's health but is also a disreputation and scandall to the House, it looking as if the children wanted victuals." But in Lamb's time Lavoisier had begun his classic work and had noted the tragic irony of the poor worker, who spends the most calories at his labor and has the least money to buy them. In 1834 the diet of Christ's Hospital was improved, potatoes being given four days a week instead of two, but the fat was reduced 10 grams, so that the net result was a loss of 81 calories. In 1914 careful records of the physical development of the boys and of the dietary were started. The war years necessitated restrictions which greatly affected the health of the boys but from 1922 on there was steady improvement, the calorie intake being increased from 2,646 in 1913, when beer was discarded, to 2,830 in 1922 and to 3,014 in 1933. These values are exclusive of food purchased by the boys in the school tuck shop. In 1919-20 boys approximating fifteen years of age had an average weight of 103.3 pounds and an average height of 69.2 inches. In 1928-29 their weight had increased on the average 10 pounds and their height more than an inch, while the younger boys showed similar improvement. The most marked changes in the dietary were an increase in fat and an increase in milk from half a pint in 1922 to nearly a full pint in 1933.

When account is taken of (1) the basal metabolism of children through the years of rapid growth, (2) their almost ceaseless activity when awake, involving the expenditure of more calories per unit of

¹⁹ Drummond, J. C. *Lane Medical Lectures: Biochemical Studies of Nutrition Problems*, page 17. Stanford University Press (1934).

weight than similar activities in adults, and (3) the necessity of energy-yielding materials to be stored in the process of growth, it is easy to see why children of all ages need a liberal energy supply. The following table will be useful in making a tentative estimate of their energy needs, although only watching the growth rate will tell whether the estimate has closely approximated the requirement for an individual child.

TOTAL CALORIES FOR CHILDREN IN TERMS OF BODY WEIGHT ^a

INFANTS

<i>Age in Months</i>	<i>Cals. per Kg. per Day</i>	<i>Cals. per Lb. per Day</i>
1 mo. to 3 mo.	120	55
4 mo. to 8 mo.	110	50
9 mo. to 12 mo.	100	45

CHILDREN

<i>Age in Years</i>	<i>Cals. per Kg. per Day</i>	<i>Cals. per Lb. per Day</i>	<i>Age in Years</i>	<i>Cals. per Kg. per Day</i>	<i>Cals. per Lb. per Day</i>
1	100	45	6	84	38
2	100	44	7	79	36
3	96	44	8	74	34
4	92	42	9	73	33
5	89	40			

BOYS AND GIRLS

<i>Age in Years</i>	<i>Cals. per Kg. per Day</i>		<i>Cals. per Lb. per Day</i>	
	<i>Boys</i>	<i>Girls</i>	<i>Boys</i>	<i>Girls</i>
10	72	69	33	31
11	71	64	32	29
12	69	60	31	27
13	67	56	30	25
14	65	51	30	23
15	64	49	29	22
16	63	47	29	21
17	62	46	28	21
18	60	44	27	20
19	58	43	26	20
20	56	43	25	20

^a Based on average weight for age and the energy allowances recommended by the Food and Nutrition Board of the National Research Council of the United States of America as revised in 1953.

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Food as the Source of Energy for the Body

The Body as a Working Machine

In Chapter 1 we learned that animal heat is a sign of combustion (oxidation) going on within the body; and that we can find out just how much food material has to be burned to produce a given amount of heat. But why the burning?

In his attempt to get an exact balance between the carbon dioxide given off by his guinea pig and the ice melted by the guinea pig's body heat, Lavoisier was led to inquire whether or not the body used more oxygen when it was cold than when it was warm; also, whether or not more heat was generated when the animal was quiet than when it was moving about. He extended these inquiries to work on man and found, as has been stated in the preceding chapters, that oxidation was increased by food, by exercise, and by exposure to the influence of cold. "This kind of observation," he wrote, "suggests a comparison of forces concerning which no other report exists. One can learn, for example, how many pounds of weight-lifting correspond to the effort of one who reads aloud, or of a musician who plays a musical instrument. . . . What fatality ordains that a poor man, who works with his arms and who is forced to employ for his subsistence all the power given to him by nature, consumes more of himself than does an idler, while the latter has less need of repair?"¹

¹ Lusk, Graham. "History of Metabolism." Barker's *Endocrinology and Metabolism*, Vol. 3, page 27. D. Appleton and Co. (1922).

One hundred and sixty years of scientific investigation have only served to bring forth more evidence that in regard to its combustion the body must be thought of as a working machine. Just as in the engine every revolution of the wheel means so much fuel consumed, so in the body the lifting of the hand, the turning of the head, the bending of the knee, or the "tightening" of all the muscles under excitement means an increase in the combustion going on. But the analogy between the body and the engine breaks down when they come to a standstill. The engine then ceases to work; but the body does not, however hard one may try not to move a muscle. The chest and the diaphragm continue to rise and fall with every breath, the heart pumps away—70 powerful contractions per minute, the muscles though at rest are not by any means fully relaxed; in other words, a great deal of internal work is going on even when one is in a state of apparent repose. The work a man does while sleeping for eight hours may actually equal the more obvious work of his daily vocation, if this be a sedentary one. The important thing to remember is that *life means work*. We burn our fuel to support the work which our bodies are doing. It varies in amount with circumstances, as we have seen, but it never ceases.

Food as the Source of Energy

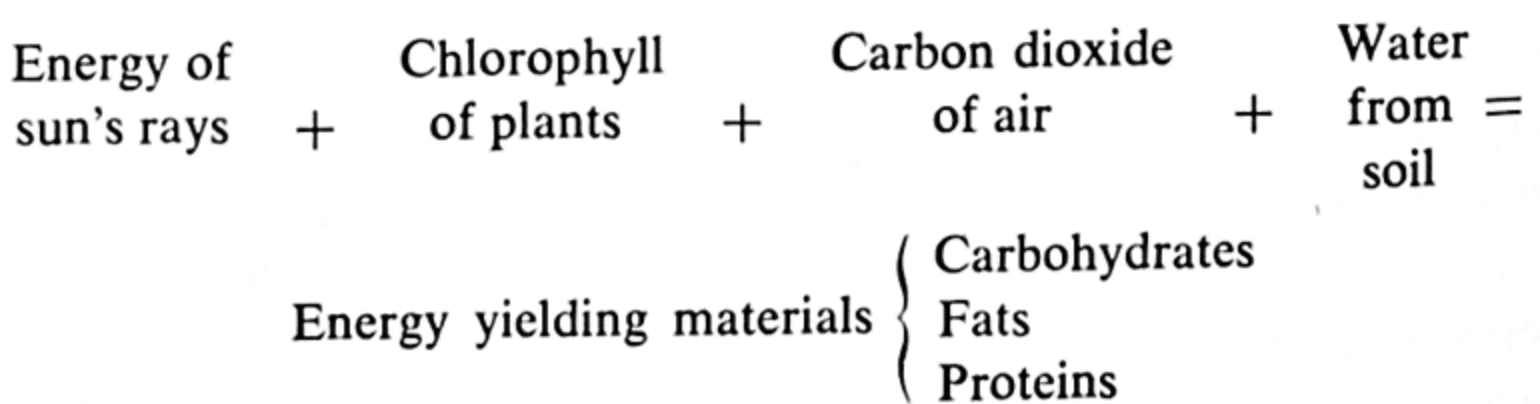
When work is to be done, fuel is demanded. This fuel must be supplied as food; it is burned chiefly in the muscles. The chemical union, in muscle cells, of the oxygen breathed in with the carbon (and hydrogen) of the food is similar to the combustion of gasoline in the automobile engine. The chemical change liberates energy which moves the machine.

The physicist defines energy as ability to do work and tells us that it exists as a force in the universe whose sum total cannot be changed. We can alter the form in which it appears and determine the place in which it shall manifest itself, but we cannot add or subtract one jot or tittle. He calls this the law of the conservation of energy. The sun is the banker of energy for the earth. Light and heat are the currency. Animals, however, cannot use these forms directly for their activities. A man cannot make a sun bath take the place of a breakfast. He must get his power to do work from his food. But how does the energy from the sun get into the food? Energy gets in through the agency of the chlorophyll (green coloring matter) of plants. In the

leaf, carbon dioxide from the air, water from the soil, and light from the sun can be bound together, making chemical compounds full of stored (potential) energy.

Let us take the corn plant as an example. Roots, stem, and leaves are chiefly woody fiber and water. The fiber will burn in a stove, yielding its stored energy as heat and light. The stem and the leaves can be eaten by cattle and, through long chewing and slow digestion, the stored energy of the plant fiber, or cellulose, may be released for the animals' benefit. A man, however, has no mechanism by which any considerable part of the energy of this fiber can be set free within his body; for him, it is not fuel. The seed, or kernel, is packed with starch grains. These will give heat when burned, but are too precious to use in a stove, for they will serve as fuel for men and animals. Furthermore, from the germ of the seed we can extract a fat, corn oil, which, too, would burn in a stove or a lamp, but is more useful as body fuel. Finally, from this same seed we can get another substance known as corn gluten, which is, like the oil and starch, inflammable in the ordinary sense and also combustible in the body.

These materials burn because they all contain a considerable amount of carbon and some hydrogen, both of which are capable of uniting with oxygen. Chemically, starch is closely related to sugar, which is also available as fuel in the body. These both belong to a group of chemical substances called carbohydrates. Corn gluten belongs to another chemical group known as proteins. Carbohydrates and fats are alike in that they each yield only three chemical elements: carbon (C), hydrogen (H), and oxygen (O). The proteins yield these three, and in addition nitrogen (N) and usually one or more of the following: sulfur (S), phosphorus (P), iron (Fe).² These last four have nothing directly to do with the use of protein as fuel, however. All the food fuels burn because of their carbon and hydrogen and all yield carbon dioxide and water when oxidized. We may think of the situation thus:



² The letters in parentheses are the chemist's symbols for these elements.

Just as the plant stores up the energy derived from the sun in the form of carbohydrates, fats, and proteins—in roots, as in the beet; in thickened stems (tubers), as in the potato; in fruits, as in the orange—so animals, eating these fuel foods in excess of their immediate needs, may store the surplus energy in their own bodies against a time of future need. Here is another point where the analogy between the body and the engine breaks down. If you pile coal upon the fire and generate more than enough steam you have to let the surplus escape; it cannot be saved for next month or next year; but if the body has a surplus of fuel it can be converted into body fat (chiefly) and stored away until actually needed. According to Armsby, a thousand-pound steer given 14 pounds of timothy hay daily will just about support himself without gain or loss. If we want him to store up food for man we must increase his fuel supply and thus give him a surplus to store.

The Measurement of Energy in Food Materials

We have recalled the fact that energy is a force which manifests itself in various forms: as work, lifting a weight or pulling a load; as heat, liberated from burning coals in the furnace; as light, from the burning tallow of the candle; as electricity, from the stored force of the river raging over the precipice; as the invisible force which spans the space between chemical atoms in a molecule, and reveals itself only when they rush together in combustion, with an impact violent enough to produce vibrations which we sense as heat or light. This force can be measured in various ways: the light, in terms of candle power; the heat, in calories; the electricity, in kilowatts; the work, as foot-pounds or kilogrammeters. Which shall we choose as our basis for the study of foods?

Since the energy of foods is to be compared with the work which the body must do, a work unit would seem most practical. Then we might use as our starting point the amount of energy required to lift 1 pound of material 1 foot into the air. In the laboratory, however, it is much easier to convert all the potential energy of a food material into heat, and having done so, it is simpler to use a heat unit directly than to recalculate each time to a work unit. Furthermore, in the resting body all the energy of internal work eventuates as heat, and whenever external work is done, heat is a by-product of the activity. Hence it is customary, although the energy of food is not used directly as heat, to measure it by a heat unit. This unit is called

the calorie and it has long been in use in physical laboratories for all sorts of energy measurements.³

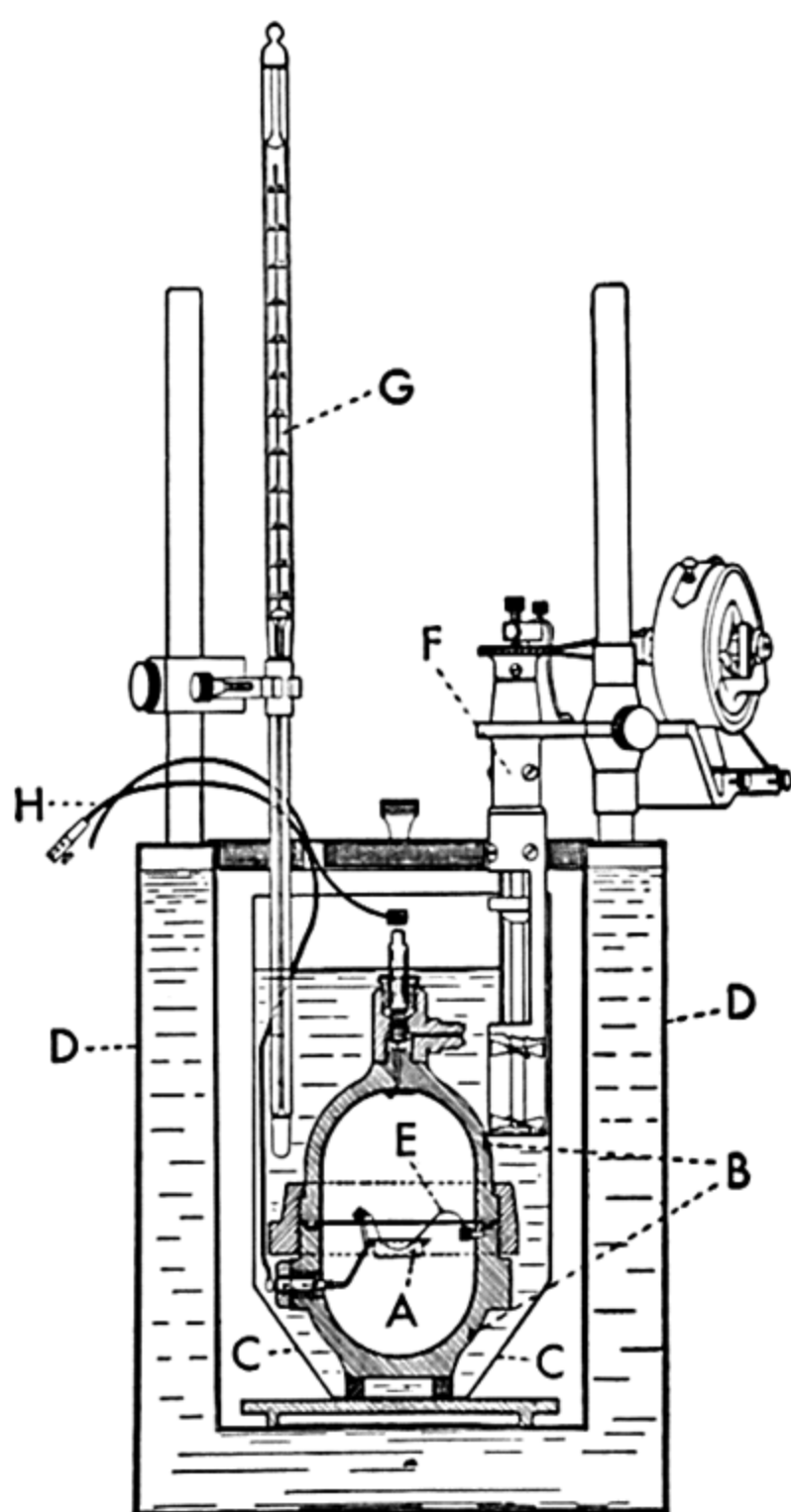
THE BOMB CALORIMETER

We cannot see a calorie any more than we see the feet of gas which the meter registers or the kilowatts for which we pay when the monthly electricity bill comes in. We are bound to depend upon the meters for those measurements and, similarly, we must depend upon a special device in determining the energy values of foods. The apparatus most commonly used is called a bomb calorimeter. It consists of an inner chamber or "bomb" made of steel and lined with gold or platinum so as to be noncorrosive, into which the material to be tested is put. This chamber is filled with pure oxygen, so that combustion may be quick and complete when a tiny "fuse" of iron wire is ignited by an electric spark. The bomb is immersed in a known weight of water, and the heat generated by the burning of the food is measured by observing the change in temperature of the water.

This apparatus is used very widely to determine the energy values of fuels, such as coal and oil, as well as of foods. While simple in principle it requires skill to operate, because the

chances of losing heat and not getting a correct measure are great.

³ The large calorie (the kilogram calorie) is taken as the standard in the



(Courtesy of the Emerson Apparatus Co., Boston, Massachusetts)

Fig. 28. Diagram of Bomb Calorimeter with Bomb in Position

A. Platinum dish holding food sample.

B. Bomb filled with pure oxygen enclosing food sample.

C. Can holding water, in which bomb is submerged.

D. Outer double-walled insulating jacket.

E. Fuse, which is ignited by an electric current.

F. Motor-driven water stirrer.

G. Thermometer.

H. Electric wires to send current through fuse.

THE OXY-CALORIMETER

Another apparatus devised for the same purpose is the Benedict oxy-calorimeter. This was devised by Dr. and Mrs. Benedict to use especially for foods, and has proved a great convenience in nutrition laboratories. The food under consideration is burned in a current of nearly pure oxygen, and the volume of oxygen consumed in its complete combustion is measured in much the same way as in the Benedict student apparatus as described in Chapter 1. Oxygen is introduced into a closed circuit, changes in volume are indicated by a spirometer, circulation is maintained by a blower, and carbon dioxide is absorbed by soda lime. The various parts are indicated in Fig. 29. Standard factors for converting liters of oxygen into calories have been obtained by use of the bomb calorimeter. For example, in burning pure sugar, if the oxygen consumption amounts to 1,000 milliliters, this will represent energy equivalent to 5 calories. For each kind of food the number of calories represented by an oxygen consumption of 1,000 milliliters has been determined once and for all, and can be applied to any quantity of the food which the apparatus can take care of.⁴

Calculation of Energy Value of Food

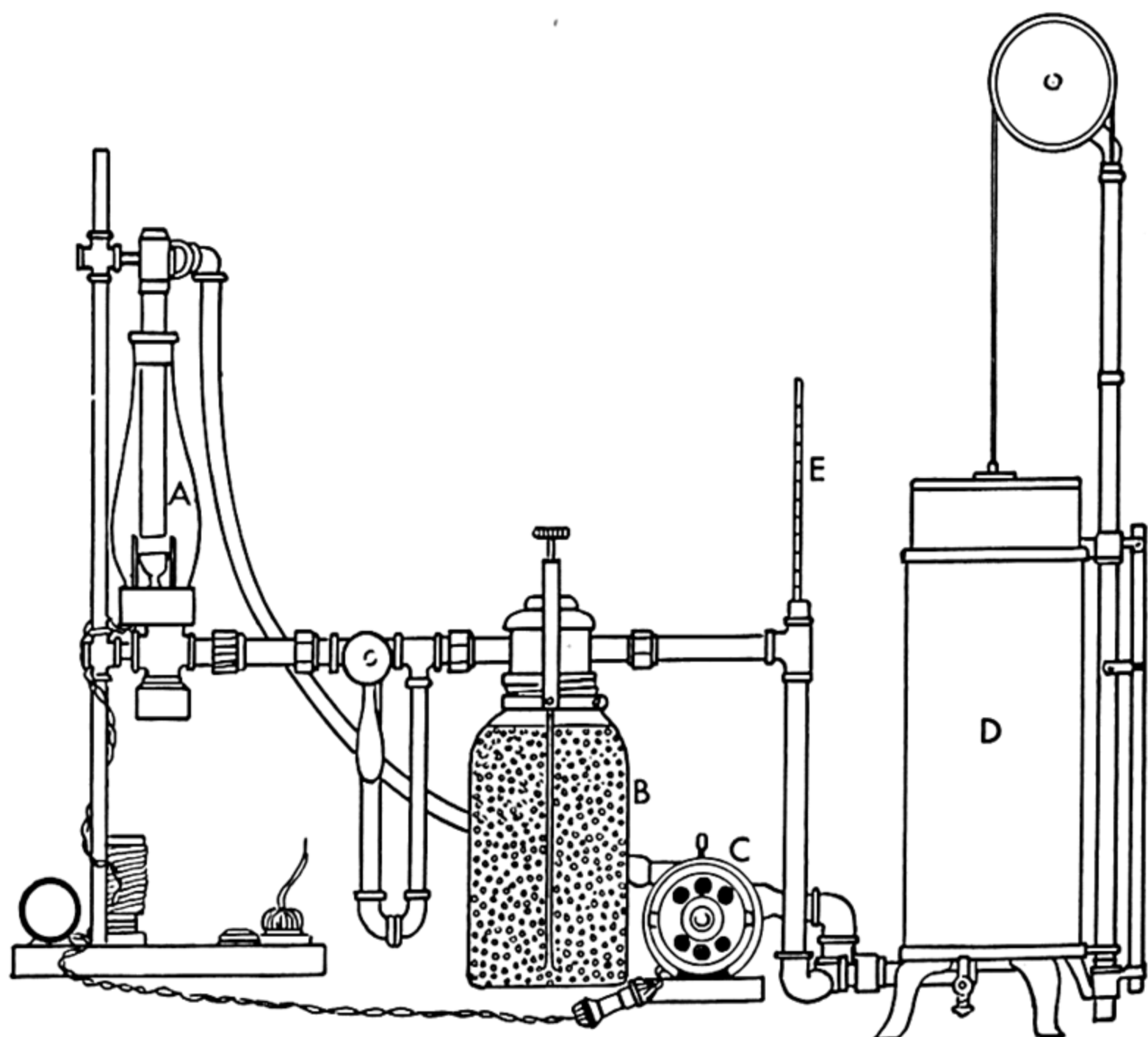
Since foods contain sometimes one kind of fuel only, as sugar; sometimes two, as beef; sometimes all three, as milk; and since these will be in different combinations and different proportions, according to the food under consideration, it saves labor to have the laboratory investigator tell us how many calories there are in a given weight of protein, fat, and carbohydrate, respectively, and then to make a few calculations ourselves, using tables of chemical composition for this purpose.⁵ The physical laboratory gives us the following average values:

science of nutrition. It is defined as the amount of heat required to raise the temperature of 1 kilogram of water 1 degree Centigrade or of 1 pound of water 4 degrees Fahrenheit. It should not be confused with the small calorie (the gram calorie) which is the amount of heat required to raise the temperature of 1 gram of water 1 degree Centigrade. In this book we use only the large calorie.

⁴ For such factors as have been determined see Benedict, F. G., and Fox, E. L. "The Oxy-Calorimeter." *Industrial and Engineering Chemistry*, Vol. 17, page 912 (1925).

⁵ A comprehensive table giving protein, fat, and carbohydrate content of food materials will be found in Taylor and MacLeod. *Rose's Laboratory Handbook for Dietetics*, 5th edition (1949), Table 35.

- 1 gram of pure carbohydrate, 4.1 calories
- 1 gram of pure fat, 9.45 calories
- 1 gram of pure protein, 5.65 calories



(Courtesy of Dr. F. G. Benedict)

Fig. 29. The Benedict Oxy-Calorimeter

- A. Combustion chamber.
- B. Vessel containing soda lime to absorb carbon dioxide.
- C. Blower to circulate air current.
- D. Spirometer to measure by contraction the volume of oxygen used.
- E. Thermometer.

The physiological laboratory tells us that we must make certain deductions from these values because protein is never quite completely burned in the body and in the case of all three foodstuffs slight losses occur due to incomplete absorption from the alimentary tract. The discounts proposed for an ordinary mixed diet by Atwater and Bryant after much careful study of the situation were: for carbohydrate, 2 per cent; for fat, 5 per cent; for protein, 29.2 per cent.

Thus we get as final figures to use in our estimates of the fuel values of food to the body:

- 1 gram of pure carbohydrate, 4 calories
- 1 gram of pure fat, 9 calories
- 1 gram of pure protein, 4 calories

If we take cane sugar as an example, our problem will be very simple, since cane sugar is 100 per cent carbohydrate, and each gram will yield 4 calories; if we take olive oil, which is pure fat, each gram will yield 9 calories; and if we take dry gelatin, which is pure protein, each gram will yield 4 calories. But if we undertake to determine in this way the fuel value of milk we shall find the situation a little more complicated, for milk contains all three:

CALCULATION OF ENERGY VALUE OF ONE GRAM OF MILK

	<i>Amount in Grams</i>	<i>Factor</i>	<i>Calories</i>
Protein	0.035	4	0.140
Fat	0.039	9	0.351
Carbohydrate	0.049	4	0.196
			<hr/> 0.687

The factors 4, 9, 4 are known as the Atwater or Atwater and Bryant factors and are, for all practical purposes, satisfactory for calculating the energy values of typical American mixed diets; but since World War II it has been felt that more specific physiological factors are needed for use in situations in which it may be necessary to deal with food supplies differing in proportions from those of the ordinary American diet. A committee of the Food and Agriculture Organization of the United Nations in 1947 took this question under consideration and recommended that for international use more specific factors should be agreed upon and used in calculating calorie values of foods. In 1949 the FAO published *Food Composition Tables for International Use* prepared by Charlotte Chatfield in which the energy values are calculated from specific factors, and in 1950 the Human Nutrition Research Branch of the Agricultural Research Service of the United States Department of Agriculture published *Agriculture Handbook No. 8 entitled Composition of Foods—Raw, Processed, Prepared*, also using the specific factors. The calorie values in Tables II and IV in the Appendix of this book are based largely

on those of Agriculture Handbook No. 8. A list of the specific physiological factors and an example of how to use them will be found in *Rose's Laboratory Handbook for Dietetics* by Taylor and MacLeod.

Standardizing Energy Values of Foods for Practical Purposes

It is worth while to spend the time necessary to learn the energy values of ordinary food materials, just as it is worth while to learn the multiplication table or the order of the letters of the alphabet. One may begin with various common units in the diet, as shown in the following table:

ENERGY VALUES OF COMMON FOOD UNITS

<i>Food Material</i>	<i>Energy Value in Calories</i>
1 almond	7
1 apple, medium	80
1 banana, medium	100
1 beet, 2" diam.	20
1 date	20
1 egg, medium	75
1 onion, 2½" diam.	50
1 orange, medium	70
1 oyster cracker	4
1 potato, medium	100
1 shredded wheat biscuit	100
1 tomato, 2½" diam.	33

One may profitably extend such tables to include one's own customary portions of all sorts of dishes, but as individuals differ very much in regard to their habits of eating, it is not possible to make standard tables on the basis of "servings," although one may find interesting and useful tables based on the judgment of certain individuals or groups as to what constitutes a "serving." ⁶

For systematic and comprehensive study of foods it is more satisfactory to adopt a standard energy unit, and the 100-calorie portion originally suggested by Irving Fisher, Professor of Economics in Yale University, has proven eminently practical. In Tables II and IV in the Appendix the weights of 100-calorie portions of many common food materials are given. With the assistance of these, and accurate scales, one may readily become familiar with the quantity of any

⁶ Calorie values of other foods will be found in Tables II and IV of the Appendix and in Taylor's *Food Values in Shares and Weights*. The Macmillan Co. (1942).

single food material required to yield 100 calories by simply consulting the table and weighing out the quantity indicated. For useful equivalents of some common weights and measures see Table XV in the Appendix.

When it comes to cooked foods the matter is not quite so simple. Tables II and IV in the Appendix give the weight of 100 calories of dry rolled oats as 26 grams. In cooking, water is added, more when the mush is thin and less when it is thick. The weight and measure of the cooked product will vary accordingly. By having a large number of persons trained in cookery prepare a 100-calorie portion to the best of their ability and taking the average, one arrives at fairly representative figures for both weight and measure of 100 calories of cooked rolled oats: measure, $\frac{2}{3}$ cup; weight, 157 grams (5.5 ounces).

The chances of variability in a portion of a food simply cooked with water, like oatmeal, are less than they are in the case of food mixtures for which there may be several recipes. This is illustrated very well by so simple a food mixture as cocoa, in which the amount of sugar and milk and the presence or absence of cream are the commonest variables. A cup of cocoa made with half milk and half water will yield only 130 calories, while if made with milk exclusively, it will yield 83 more. If 2 tablespoons of cream and an extra teaspoon of sugar are added, the energy value will be more than double that of the first cup, as shown in the following table:

ENERGY VALUE OF COCOA PREPARED IN DIFFERENT WAYS

<i>Cocoa I</i>	<i>Cocoa II</i>	<i>Cocoa III</i>	<i>Cocoa IV</i>
Milk, $\frac{1}{2}$ cup	Milk, 1 cup	Milk, $\frac{1}{2}$ cup	Milk, 1 cup
Water, $\frac{1}{2}$ cup	Cocoa, 2 tsp.	Water, $\frac{1}{2}$ cup	Cocoa, 2 tsp.
Cocoa, 2 tsp. ^a	Sugar, 2 tsp.	Cocoa, 2 tsp.	Sugar, 3 tsp.
Sugar, 2 tsp.		Sugar, 3 tsp.	Cream, 2 tbsp.
		Cream, 1 tbsp. ^b	
Calories			
in recipe, 130	213	180	297
100-calorie			
portion, $\frac{2}{3}$ cup	approx. $\frac{1}{2}$ cup	approx. $\frac{1}{2}$ cup	$\frac{1}{3}$ cup

^a Tsp. stands for teaspoon.

^b Tbsp. stands for tablespoon.

From these examples it is obvious that the calorie values of portions of cooked food materials depend upon the recipes used in preparing them and that, therefore, such figures must be used with caution unless the recipes are known or the ingredients indicated. With

suitable tables ⁷ of food values, however, it is possible to estimate the energy yield of a day's ration with a degree of accuracy sufficient for all practical purposes.

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⁷ For food values of recipes see Rose's *Feeding the Family*, 4th edition, pages 351–398. The Macmillan Co. (1940); Taylor's *Food Values in Shares and Weights*. The Macmillan Co. (1942); Watt and Merrill, *Composition of Foods—Raw, Processed, Prepared*. Agriculture Handbook No. 8, U.S. Department of Agriculture (1950).

Food in Relation to Growth and Weight Control

The normal human body has firm, elastic muscles and a moderate store of fat widely distributed over the body, under the skin, around the visceral organs, among the muscle fibers, and elsewhere. This fat is advantageous as an insulator, saving the combustion of fuel for the production of heat under stimulus of cold. It also serves as padding for the viscera and the muscles, as support for the eyeball and for the kidneys, protecting against jars and blows, and as a storehouse of energy upon which the body can draw when for any reason food is not immediately forthcoming.

We burn our fuel foods according to the demand of the muscles for energy, not according to the amount eaten. Whatever is eaten in excess of immediate need is stored for future use. Carbohydrate foods (sugar and starch) are stored as glycogen in the liver and to some extent in the muscles; however, since the body's capacity to store glycogen is limited, when the glycogen storehouses are full the incoming carbohydrates, if not immediately needed, will be chemically changed and packed away in the more concentrated form of fat. Fat eaten as such is also stored in the body practically unaltered if not required as fuel at once. Protein, if eaten in large quantity, tends to burn itself off on account of its stimulating effect upon combustion. The well-nourished body carries some reserve protein, but has no capacity for storage of any large surplus. In this respect protein differs markedly from carbohydrate and fat.

When a person begins to fast, the stored glycogen is burned first and is ordinarily reduced to a minimum in a day or two. Then fat is

drawn upon along with some protein, and the length of time the person can fast without harm is practically determined by his fat reserves.

Vigorous human beings always carry some reserve of body fat. The best information we have as to the relationship between body weight and health is derived from the data of life insurance companies. These give us the body weight for age and height which has most frequently been found associated with health and longevity. The adult who deviates much in either direction from the so-called normal range should have a complete physical examination. Schools and colleges are increasingly attentive to the desirability of such examinations for students and provide for them through their medical or other health services, while more and more other health agencies are making such examinations possible for the citizens at large.

An adult can, however, determine whether he is above or below average weight for his age and height by the use of standard age-height-weight tables (see Appendix, Tables VIII to XI). It is generally accepted today that the best weight for an adult is the weight for his height at age twenty-five. Deviations of 10 per cent or more from this in either direction may or may not be significant, but it is advisable to seek the explanation for a deviation of more than 15 per cent, in whichever direction it occurs, and to consider its effect on health and efficiency.

Another procedure for determining whether or not an individual is overweight has been proposed by Behnke, Feen, and Welham¹ of the United States Navy. On finding that 17 "all American" football players could be classified as unfit for military service and as not eligible for first-class insurance by reason of overweight they were interested to determine the specific gravity of these and other men on the ground that overweightness due to too much adipose tissue should result in a low specific gravity. The volume of the subject was determined by weighing him in air as usual and then in water by suspending him below the surface of the water on a line connected with a spring balance which gave his weight. It was found that the specific gravity of healthy men between twenty and forty years of age ranged from 1.021 to 1.097 and that a value of 1.060 or less indicated excessive fat. They also found that the difference between

¹ Behnke, A. R., Jr., Feen, B. G., and Welham, W. C. "The Specific Gravity of Healthy Men. Body Weight-Volume as an Index of Obesity." *Journal of the American Medical Association*, Vol. 118, page 495 (1942).

thoracic and abdominal girth increased as the specific gravity increased, averaging nearly 7 inches in the lean naval man and the athlete of high specific gravity and only $4\frac{1}{2}$ inches in the men of low specific gravity. Of the 17 men studied, 11 fell into the group with high specific gravity and should have been judged to be in excellent physical condition if absence of excess fat is taken as a criterion of physical fitness.

Another method² for estimating body fat is that of measuring, by means of calipers, the thickness of a double layer of the skin at several points on the body surface. Normally the layer of fat under the skin is $\frac{1}{4}$ to $\frac{1}{2}$ inch thick. Deviations of skin folds from this range of thickness can be used to estimate the degree of fatness of the body.

Still another method² depends upon the fact that the water content of the lean, fat-free body mass is very constant. The water content is determined by injecting into the body a water-soluble drug, such as antipyrine. After allowing time for complete distribution of the drug throughout the water content of the body, a sample of blood is withdrawn and the concentration of the drug in the plasma determined. From the dilution of the drug it is possible to estimate the total amount of body water and from this the amount of body fat.

Section 1. SHORTAGE OF CALORIES

Undernutrition in Adults

It is not desirable for adults to carry too great a store of reserve fuel, as it may become a handicap instead of an advantage. On the other hand, it is possible for the adult to become habituated to living on too low a nutritional level, so that he is unconscious of any disadvantage and will protest that he is "perfectly well," while as a matter of fact he is more liable to both physical and mental fatigue, to nervous diseases, to tuberculosis and other infections, than if he were living on a higher nutritional plane. This is corroborated by investigations made by Blunt and Bauer at the University of Chicago in regard to the basal metabolism and food habits of 19 underweight college women; 11 of these were found to be eating less than 500 calories

² Rathbun, E. N., Morales, M. F., Smith, R. E., and Pace, N. "Studies on Body Composition: I and II." *Journal of Biological Chemistry*, Vol. 158, page 667 (1945).

a day in excess of their basal metabolism. They confessed that they became tired very easily and yet they were quite certain they were eating enough and could not possibly eat any more. When one of them, who weighed only three-fourths as much as she should, was finally induced to increase her food consumption, she admitted that it was astonishing how much more she could eat and how much better she felt. Very often women even less severely underweight than this one suffer from chronic fatigue to which they have become so accustomed that they are utterly unaware of how much better they might feel. The combination of a long night's sleep and an increased food intake will often increase vitality surprisingly.

Further evidence of the effect of living on a low nutritional level is furnished by the study made by Benedict and some of his associates on a squad of 12 young men whose habit before the experiment was to consume from 3,200 to 3,600 calories daily. For the first three weeks they were limited to 1,400 calories a day, with a consequent fall in body weight amounting to 12 per cent of their original weight. They were then able to maintain this reduced weight on 1,950 calories daily, and by numerous tests gave evidence that their efficiency in work of various sorts was not measurably impaired. However, they said that they felt less energetic, and had to drive themselves to their tasks instead of undertaking them with abounding energy and a surplus of good spirits. In gymnasium tests they gave out sooner than when living on the higher nutritional level and took less pleasure in their performances.

A similar but more comprehensive study of longer duration by Keys and his associates at the University of Minnesota has already been described in Chapter 2, page 27. Thirty-two conscientious objectors who maintained their average body weight on an intake of 3,492 calories daily during the pre-experimental period lost 24 per cent in body weight when they were reduced to a level of 1,547 calories daily for a period of six months. The symptoms which developed during the experimental period were characteristic of those of famine victims and are described on pages 27 to 28.

Undernutrition in Children

There is no simple method of determining a child's nutritional status. There must be well-developed muscles with good tone, normally functioning digestive and nervous systems, evidences of a good

blood supply, and of skin and mucous membrane in prime condition. Furthermore, there must be assurance that there are ample body reserves of those substances whose storage is known to be favorable to the best development, such as calcium and vitamin A and a certain amount of subcutaneous fat. Growth at a good rate is characteristic of the well-nourished child, but true progress can only be determined by weight and height records over considerable periods of time. And it is not enough that a child carry a certain number of pounds for his height. He may still be flabby and pale, with poor teeth and bad skin, his only nutritional virtue being his subcutaneous fat. Weighing and measuring give information of great value if consistently done, month by month and year by year, but they alone will not separate the well-nourished from the ill-nourished.

Other points upon which specific information is desirable are the condition of the teeth, the progress of ossification of the bones in relation to age, the amount of hemoglobin and number of red cells in the blood, the state of the appetite, the soundness of sleep, and the general zest for life.

In this section we are concerned with undernutrition due to shortage of total calories. Children's energy needs are so high that it is difficult for them to accumulate any reserve of fuel in the form of body fat, and when they do, it is usually used up in the next spurt of growth in height. In the process of growth the body must store materials having energy value. A deficiency of calories only will result in stunting, even if all other dietary essentials are adequately supplied. This can easily be demonstrated by means of laboratory animals. In Fig. 30 is shown a young male rat and its litter brother. The upper one was allowed just two-thirds as many calories as the lower one, but the two diets furnished both animals with adequate amounts of all other dietary essentials. In nine weeks on the restricted diet the one rat made no significant gain in weight although he was very lively and gave every appearance of being in good health, while the other grew steadily. When the stunted animal was changed to the full ration it doubled its weight in a single week and continued to gain at a rapid rate until it attained the same weight as its brother.

A young child with little adipose tissue is an easy prey to malnutrition, hence it is better for every growing child to be a little overweight rather than underweight for his build. Tables to be used as a guide for desirable weight of children will be found in the

Appendix (Tables V, VI, and VII). In estimating the food needs of underweight children one should use the desirable weight for height as given in these tables rather than actual weight. The calorie allowances per unit of body weight will be found on page 84. The less easily a child fattens, the greater the need to feed him liberally so that sufficient calories may always be available to sustain any spurt of growth.



Fig. 30. The Effect of Restricting Calories Only Is Shown in These Two Animals

Both are the same age. The upper one had only two-thirds as many calories per day as the lower one.

The number of children given annual physical examinations is rapidly increasing and it is to be hoped the time will soon come when every child can be tested periodically from birth until he is able to assume responsibility for securing his own health examinations. That so many of our American school children are reported to be undernourished is an indication of regrettable ignorance and carelessness. While some of the underweight children are baffling problems, the majority of them respond to an improvement in their mode of life, including an adequate diet; the others should be under the care of physicians, either privately or at child welfare clinics, so that the

fundamental causes of their physical inadequacy may be skillfully investigated and as far as possible removed.

The Causes of Undernutrition

Ordinarily we depend largely upon appetite as a guide to food consumption, but this cannot be relied upon without intelligence to direct it. Just as an extra pat or two of butter stored every day for ten years may transform a 150-pound man into a case of obesity, so a consistent shortage of calories may result in undernutrition. This deficit may be unsuspected if the person follows his routine of three meals a day. As Morgulis aptly remarked in his treatise on undernutrition: "A person, engaged in the performance of heavy work on a dietary allowance which supplies energy for mild tasks only, will be as truly in a state of chronic inanition as is one who through accident, disease or misfortune is obliged to sustain himself on a limited quantity of food. In either event there will be a negative balance between the income and output of energy, a shortage which the organism must make good by infringing slowly but nonetheless persistently upon its stored reserves." ³

No appetite is entirely trustworthy; if no attention is paid to the energy value of food, fluctuations in the amount eaten from meal to meal and day to day may be very great. In a study of the individual food consumption of a group of healthy and presumably well-fed girls from ten to twelve years of age,⁴ living in the same house and eating at the same table, great variation was found in the amount eaten from day to day. This was especially true in regard to the dinners. By weighing each girl's food for a number of days it was discovered that the greatest single cause of this variation was the presence or absence of milk in the menu. Within a month, 61 dinners weighed on days when milk was not given as a beverage averaged 619 calories, while 23 dinners when milk was supplied averaged 1,038 calories, an increase of 68 per cent. The study also showed that if the main dish and the dessert both happened to be low in calories

³ Morgulis, Sergius. *Fasting and Undernutrition*, page 261. E. P. Dutton and Co. (1923).

⁴ Rose, M. S., and Gray, C. E. *Relation of Diet to Health and Growth of Children in Institutions*. Child Development Monograph No. 2. Bureau of Publications, Teachers College, Columbia University (1930).

when no milk was furnished a dinner might have only half as many calories as the one the next day.

Similar observations were made by Wait and Roberts⁵ at the University of Chicago in connection with studies of the energy intake of adolescent girls in institutions. One of the girls consumed on Monday 1,964 calories; Tuesday, 2,231; Wednesday, 2,039; Thursday, 1,804; Friday, 1,110; Saturday, 2,015; and Sunday, 3,116. The difference between her maximum and her minimum was 2,006 calories. The ease with which two people sitting at the same table can vary their food intake is shown by the two breakfasts from the same menu as follows:

TWO BREAKFASTS FROM THE SAME MENU

<i>Food</i>	<i>Breakfast I</i>		<i>Breakfast II</i>	
	<i>Measure</i>	<i>Calories</i>	<i>Measure</i>	<i>Calories</i>
Orange	$\frac{1}{2}$	35	1	70
Sugar	none	0	2 tsp.	33
Cornflakes	$\frac{1}{2}$ cup	40	$\frac{3}{4}$ cup	60
Sugar	none	0	1 tsp.	17
Milk	$\frac{1}{2}$ cup	55	$\frac{1}{2}$ cup	83
Toast	1 slice	63	2 slices	126
Butter	$\frac{1}{2}$ tbsp.	50	1 tbsp.	100
Coffee	1 cup clear	0	with 2 tbsp. light cream	67
Sugar	1 tsp.	17	2 tsp.	33
		<hr/> 260		<hr/> 589

If one trusts solely to inclination, how much one eats depends largely upon the attractiveness of the food. People on low incomes without vigorous appetites often find little inducement to eat the kind of food on their tables. They cannot afford the alluring cream, butter, eggs, and fruit which add more calories than necessary to the diets of the more affluent, to say nothing of other foods which by attractive color, form, and flavor make eating the "most popular indoor sport."

Sometimes the root of undernutrition is worry—a proverbial destroyer of appetite. One young woman who wished to reduce her weight and found great difficulty in doing so was heard to exclaim,

⁵ Wait, B., and Roberts, L. J. "Studies in the Food Requirements of Adolescent Girls. II. Daily Variations in the Energy Intake of the Individual." *Journal of the American Dietetic Association*, Vol. 8, page 323 (1932).

"I'd go down fast enough if I could only get up a big worry!" Children often suffer from underweight due to unhappiness and nervousness caused by an unfavorable home atmosphere. Emotional excitement causes outpouring of adrenaline and increases the energy expenditure, while at the same time the environment and the character of the diet may tend to decrease appetite. The result is inevitably a discrepancy between energy intake and output and the child loses weight. Such children improve amazingly in regard to food consumption and body weight when changed to a more favorable environment.

Psychological factors play a large part in determining the food intake of children. This was clearly demonstrated in studies of children observed while eating in their own homes reported by the University of Chicago.⁶ This survey included 50 farm children, 100 city children from comfortable or well-to-do homes, and 100 children from a poor section of Chicago. Everything that happened during at least one meal in each home was recorded—the foods served, the amounts eaten, the time required, the part played in the meal by adults present, etc. In the farm group, only one-third showed unwillingness to eat while of the 100 children in the well-to-do group, two-thirds showed varying degrees of resistance to eating, 40 of them requiring constant coaxing and taking long periods of time to complete the meal. Of the 100 children from the poorer section of the city, only 14 were classified as "non-hungry" and only 5 of these were described as being extremely so. Psychological factors were noted as the chief cause of the failures in the well-to-do group in view of the fact that their diets were superior as to types of food served and spacing of the meals, medical and dental care was adequate, and sleep and play were well regulated. In the other two groups psychological factors were favorable—the children ate with other hungry members of the family rather than alone. The parents were busy either serving or eating and there was a minimum of coaxing to eat. Although physical factors undoubtedly played some part in creating the eating problems encountered, it was felt that in the great majority of these cases psychological factors played the predominant part.

⁶ Martin, E. A. *Roberts' Nutrition Work with Children*, 3rd edition, page 135. The University of Chicago Press (1954).

Another common cause of inadequate appetite and undernutrition is fatigue. Several hundred college women in response to a questionnaire gave this as the commonest cause of failure of appetite in their own personal experience. In young children fatigue is undoubtedly very frequently responsible for reduced food intake, and probably affects in other ways the efficient use of food by the body. Children need to be carefully watched as regards the time spent in sleep and rest and to be safeguarded against playing to the point of exhaustion.

Many times loss of appetite is due to some physical defect or disease: enlarged tonsils and adenoids, interfering with full respiration; infected teeth and tonsils, constantly poisoning the body; and latent infectious diseases, such as tuberculosis with its fickle appetite, are among the common causes of undernutrition reported by child health stations and clinics. Not only tuberculosis but also various diseases of the nervous system and of the alimentary tract seriously impair appetite and in this and other ways bring about undernutrition.

Still another cause of poor appetite may be too low an intake of thiamine. This vitamin functions as a regulator of both appetite and intestinal motility. This will be discussed more fully in a later chapter.

While simply increasing the total amount of food will result in higher intake of all the constituents which accompany the calories, better selection of the sources of the calories will yield still more satisfactory results. This is interestingly shown by two studies, one made by Sherman and Gillett in 1914-15 and the other by Gillett and Rice in 1928. Each study was based on the food purchased by approximately 100 city families on low incomes. In 1914 the most common errors in the diets of 92 of the families which were uninfluenced by educational work on the part of the nutritionist were too much meat and fish and too little milk, fruit, and vegetables, resulting in deficiencies in calories, calcium, and vitamins, and often in iron. The study in 1928 included 100 families which had received no special instruction in the essentials of diet, but even these spent a larger percentage of their food money for milk, fruit, and vegetables, with a corresponding decrease in the amount spent for meat and fish. This wiser expenditure resulted in fewer dietaries with mineral and vitamin deficiencies.

Another study which shows the effect of nutrition education on

food habits was reported by Bovee and Downes⁷ in 1941. In this case an intensive nutrition program was carried on in the homes of 90 families throughout a period of nine months while an additional 45 families receiving no instruction were observed during the same period as a control group. The children of these 135 families were rated on food and health habits at the beginning and end of the nine months. The ratings of the children in the control group showed very little change, but those of the children of the 90 families in which the teaching was done showed significant increases in the use of milk, fruits and tomatoes, vegetables, and eggs.

Nutrition education is unquestionably needed if we are to have adequately nourished children. This is clearly shown in a report by General Mills, Inc., in 1951, of the eating habits of 60,000 school children in 38 states in the United States. Three-day food records were carefully kept and the results compared with the recommended allowances of the National Research Council. Of the 60,000 diets represented only 33 per cent could be classified as good, 27 per cent were rated as fair, while 40 per cent had to be ranked as poor.

That significant practical results can be obtained by a nutrition education program was convincingly shown during the years 1949 to 1954 by Archibald,⁸ now Director of the Nutrition Division, Department of Public Health, Nova Scotia. The study was carried out on Cape Sable Island, a small island off the coast of Nova Scotia whose people are typical of fishing communities. A carefully detailed survey was made of the schools and school children, the families (their size, their age and sex make-up, where they lived, their occupations, their living conditions), and the nutritional status of the population. With this information in hand a random sample including one-fifth of the families of the Island was chosen, visited, and asked to cooperate in the program. Then followed five years of nutrition education programs in the schools, the homes, and the communities. At the end of the five-year period a re-survey was conducted using the same methods as in the original survey. It was found that dietary inadequacy had been reduced from 18.5 per cent to 8.4,

⁷ Bovee, D. L., and Downes, J. "The Influence of Nutrition Education in Families of the Mulberry Area of New York City." *The Milbank Memorial Fund Quarterly*, Vol. 19, page 121 (1941).

⁸ Archibald, Juanita H. "A Nutrition Education Program in Cape Sable Island." *Project for the degree of Doctor of Education in Nutrition*, Teachers College, Columbia University (1952).

obesity from 3 per cent to 2.4, underweight from 6.6 per cent to 4.9, low hemoglobin from 36.5 per cent to 15.4, and gingivitis from 45.4 per cent to 38.9 per cent. In this program the nutritionist had the full cooperation of medical health officers, the assistant superintendent of education, the inspector of schools, physicians, and public health nurses as well as that of the teachers.

Safeguarding Digestion

Sometimes attempts to gain weight are discouraging because the person's digestive system is unequal to the new demands abruptly made upon it. This may be due in large measure to a deficiency of thiamine. The deficiency may be no more than enough to produce a poor tone of the walls of the alimentary tract, but since good digestion is very directly related to vigorous, well coordinated movements in all parts of the digestive system, minor digestive ills result. The great advances in the feeding of infants and young children without digestive upsets are probably due in large measure to the recognition of thiamine as essential to nutrition. A person who needs to improve his appetite should choose foods rich in this vitamin. The thin person needs first to make himself as well as possible, so that he will agree with his food. In addition there are some precautions which it is well to take. For one thing increases should not be too sudden. The girl who learned that peanut butter was high in calories and proceeded to dispose of half a pound (1,312 calories) a day in addition to her regular diet came quickly to grief because she had given her alimentary tract a task to which it was unaccustomed. It is not enough to know only how much energy is needed; we must also know how to furnish it so as to prevent disturbance of the machinery. The three kinds of fuel food are used to best advantage when carbohydrate predominates, and neither fat nor protein is present in very high proportion. Since fat is our most concentrated form of fuel, it has to be used with discretion or digestion may be disturbed and we will defeat our own ends. Protein is easy to digest but is best used in moderate amounts if we would get its full contribution to the total energy intake. Protein alone burns wastefully, many calories being then unavailable for either work or storage. (See Chapter 8.) Carbohydrate in the form of sugar is most attractive, but sugar blunts appetite unless carefully managed. Mrs. Squeers of Dotheboys Hall

knew this, for she gave treacle (molasses) to her wretched protégés “partly because it spoils their appetites and comes cheaper than breakfast and dinner.” Sugar in concentration irritates the stomach and may be the cause of headaches, skin eruptions, and other ills.

For the greatest comfort, food should digest fairly rapidly. This is especially true if a larger amount than usual is to be eaten. As rapidity of digestion is fostered by having the food in fine particles when it enters the stomach, mastication becomes a special virtue.

Fat, digesting slowly and tending to retard the digestion of other foods, especially those rich in protein, must not be used too freely, for slow digestion tends to impair appetite for the next meal. Fat meats, such as pork, are an excellent example of food slow to digest because of fat mixed with the protein.

The exact number of calories which any person will require to induce gain in weight cannot be determined definitely in advance, but must be gauged by watching the scales. Those who do not fatten easily need all the more to learn to live on a high nutritional plane and safeguard themselves against serious undernutrition.

Section 2. SURPLUS OF CALORIES

Who does not remember Mrs. Manson Mingott, the “venerable ancestress” in *The Age of Innocence*, whose habit it was to sit in her room on the ground floor waiting for life and fashion to come to her, since she was unable to follow them even to the grand reception room on the second floor of her Fifth Avenue mansion? Mrs. Wharton has described her inimitably: “The immense accretion of flesh which had descended on her in middle life like a flood of lava on a doomed city had changed her from a plump active little woman with a neatly-turned foot and ankle into something as vast and august as a natural phenomenon. She had accepted this submergence as philosophically as all her other trials, and now, in extreme old age, was rewarded by presenting to her mirror an almost unwrinkled expanse of firm pink and white flesh, in the center of which the traces of a small face survived as if awaiting excavation. A flight of smooth double chins led down to the dizzy depths of a still-snowy bosom veiled in snowy muslins that were held in place by a miniature portrait of the late Mr. Mingott; and around and below, wave after wave of black silk

surged away over the edges of a capacious armchair, with two tiny white hands poised like gulls on the surface of the billows.”⁹

Many another woman has been forced by the accumulation of body fat so common with advancing years to keep off her feet or suffer because her body has become too heavy for them to carry. We realize the handicap of obesity when it thus impedes locomotion and engenders flat foot, but we should also realize that the internal organs are working under a handicap like that of the feet. The muscles when clogged with fat become soft and flabby; the heart in particular suffers in this way. The circulation of the blood is impeded and this in turn makes the work of the weakening heart more difficult and the strain on the blood vessels greater. Liver, kidneys, and pancreas all are at a disadvantage, and how long they can continue to function properly depends on their native endurance.

About 25 per cent of the population of the United States is known to be overweight and to such a degree as to cause impairment in health. The mortality rate for this group is well above average. Obesity is associated with high death rate from cardiovascular-renal disease, diabetes, liver disease, and in childbirth. In diabetes, the death rate is three times as high in the obese as in those of average weight and in liver cirrhosis among men more than twice as high. It is well established that mortality rates for overweight men are 50 per cent greater than the expected normal and for overweight women 47 per cent greater. Such figures have resulted in obesity being called our “Number One Public Health Problem” and explain why life insurance companies are reluctant to place standard insurance on people with marked overweight, and where it is excessive, may refuse insurance altogether. This attitude of the insurance companies shows that they consider being overweight a very serious disability. Recent studies by the Metropolitan Life Insurance Company show that weight reduction by overweight people apparently increases the chances for living longer. As a result of this finding overweight people who have reduced have been granted standard premium rates after having been charged higher rates because of their excess weight.

It should be pointed out here that the terms “overweight” and “obesity” are used differently by different writers. Some consider them synonymous and use them interchangeably; others use overweight to indicate a body weight 15 to 25 per cent above desirable

⁹ Wharton, Edith. *The Age of Innocence*, page 25. D. Appleton and Co. (1920).

weight and reserve the term obesity for weights 25 per cent or more too high; still others would limit the term obesity to those cases in which the excess weight is due, as in Mrs. Mingott's case, to abnormal accumulation of fat in the body and use the term overweight for excess weight due to a tall and heavy frame and corresponding muscle development. For methods commonly used to estimate fatness see pages 98 and 99.

Causes of Obesity

That obesity is the result of an excessive appetite leading to an intake of calories greater than the expenditure of the individual is universally agreed, but the cause of this excessive appetite is not well understood as yet. In most cases it is believed to be the result of abnormal behavior of an appetite-regulating center located in the hypothalamus, which is situated near the pituitary gland in a region of the brain in which are located also other regulatory centers such as those governing water balance, body temperature, sleep, etc. Dr. Jolliffe, Director of the Bureau of Nutrition in the New York City Department of Health, has proposed the name "appestat" for this appetite regulator. It is known that damage to the hypothalamus may result from disturbances in other centers located near it and may cause excessive appetite. Some forms of damage result in loss of appetite (anorexia). This appetite-regulating center can be conditioned to demanding a higher intake of food than normal by simply habitually overeating. Fortunately, an appestat thus conditioned can be educated back to normal by reducing food intake, a process which takes time, patience, and will power.

Dr. Mayer of the Harvard University School of Public Health has shown in experimental animals that desire for food is felt only when the level of glucose in the blood is reduced beyond a certain point. In human beings he has found that the difference between the levels of glucose in arterial and venous blood (called delta glucose) serves as an indicator of the availability of glucose to the regulatory center in the hypothalamus. Small differences were found to correlate well with feelings of hunger on the part of his subjects. When the feelings of hunger had disappeared after eating, the differences were found to be larger.

From his extensive research work in this field, Mayer concludes that excessive appetite is due to at least three (and probably more) factors, namely, heredity, environment, and physical or mental in-

jury. As an example of obesity due to heredity he cites the practice of animal breeders in producing strains of beef cattle, hogs, and poultry in which fatness is transmitted from one generation to the next. In human beings, studies have been reported by various investigators of family occurrence of obesity. To cite only two of these—Rony, in a study of 250 obese patients, found that 69 per cent had obese parents (either one or both) and Angel reported a study in which he found that half the offspring of parents, one obese and the other normal in weight, were obese, while two-thirds of the children of parents both obese were obese. In these cases both hereditary and environmental factors are doubtless involved. The children of overweight parents may be overweight simply because of family eating habits, for example, too great indulgence in generous quantities of foods high in calorie value. If in any case there is some indication of glandular abnormality a physician who specializes in the treatment of such conditions should be consulted. Physicians report, however, that they rarely see cases of obesity which they can call inherited. Emphasis needs to be placed on the fact that we inherit our body framework, not our body weight. The weight in the great majority of cases, is under our control. This should be kept in mind when obese individuals excuse their condition by saying "It runs in my family and can't be helped."

Examples of environmental obesity are such cases as those due to the nature of the diet, immobilization due to convalescence, and inactivity in general. Overeating may also be the result of emotional disturbances or frustrations, the individual resorting to food as compensation for feelings of insecurity or to relieve tensions.

Physical or mental injury such as surgical damage to the brain or to the hypothalamus or other centers near it may disturb the appetite-regulating center and cause excessive appetite which, if indulged, will lead to overweight.

All investigators in this field agree that much research remains to be done before the causes of obesity can be fully known and understood.

Control of Body Weight

In view of the preceding discussion and the fact that the proportion of older people in our population is increasing markedly, there can be no doubt as to the need for controlling body weight. The best

first step would be that of preventing overweight by watching one's weight as one grows older with the object of keeping it within the normal range for age twenty-five. A tendency to increase in weight beyond this range should be checked immediately by making changes in diet and activity. We have seen that the basal metabolism of adults falls slightly year by year. Exercise seldom fails to diminish in duration and intensity; and emotional intensity declines as the strife of life abates and the fruits of labor are enjoyed; thus stimulus of the adrenal glands to energy expenditure becomes less. Yet the appetite for food continues or even increases, and more and more is eaten which is not needed, the extra fuel being stored as body fat. When riding in automobiles, watching movies, sitting at bridge parties, or looking at television are the most active forms of sport, how many calories in excess of the basal metabolism will be spent?

If we propose to lead sedentary lives, we should learn to lead them well. The greatest obstacle is habit. One must plan a food program which one can remember. The best way is to determine the number of calories needed for the day and distribute them equally among the three meals. It has been reported by several investigators that skipping a meal does not bring about weight loss. The calories permitted must be chosen from foods rich in protein, mineral elements, and vitamins so that no dietary essential except calories will be reduced. It is good practice in starting on a reducing program to plan for not less than 1,200 calories per day. In so far as possible the diet should include the foods to which the subject has been accustomed, but in many cases re-education in this respect will be found necessary. Learning how to substitute foods for each other is important in order that the diet may not become monotonous and be given up. It is exceedingly important to remember that the limitation must be in calories only. Every other dietary essential must be kept at the optimum level. The modern science of nutrition has shown the way to make a reducing diet which is not only safe but will actually improve health. The details of planning such diets are discussed in Chapter 25.

Control of Appetite

Hunger is a great inconvenience when one wishes to reduce one's food intake. Hunger pangs are extremely uncomfortable and hence it is well to seek some way to allay them. Sometimes drinking water

will assuage them temporarily. Eating food with much vegetable fiber is a help as it gives a sense of fullness, which is a part of the normal satisfaction of hunger. Lettuce, cabbage, string beans, celery, brussels sprouts, asparagus, chard, and other greens should be indulged in freely. Raw fruit such as apples, oranges, grapefruit, and other fruits in season should, so far as possible, take the place of other desserts. Some fat is a help in controlling hunger and can be used if sufficient attention is paid to the total calories, which, of course, are rapidly increased by this concentrated form of fuel. The fat should be put where it will count most, on the table where one can see it, and not in the food while cooking.

Adjusting Energy Intake and Energy Expenditure

The scales should be watched week by week. Gain or no gain is the final test of the diet. If one is gaining, there are too many calories. Adjust them until weight remains stationary; or, if overweight, until losing at the desired rate, which should not be over two pounds a week. Remember that 200 calories a day stored mean 17 pounds of body fat in one year, and that one insignificant chocolate caramel yields 50 calories; one small bar of sweet chocolate, 125 calories; one sundae at the fountain, 500 calories; one chocolate malted milk with ice cream, 700 calories.

Loss in weight may not be regular. Fat burned off may be temporarily replaced by water with little or no change in weight for some time (see page 123). Then water may be lost rapidly and weight may fall, only to remain stationary again as water accumulates once more. Later, this water will be lost, and then the reduction in fat, which has been going on all the time, becomes evident. If the calories taken are below those expended body fat must be used as fuel. There is no escaping this law. If the body persistently retains water, so that after some weeks the weight has not gone down, a physician skilled in the pathology of the endocrine glands should be consulted. The pituitary gland, especially, exercises a control over the water of the body.

In addition to limiting the calories, it may be desirable to increase the energy expenditure by exercise which should be moderate and regular. If too strenuous exercise is indulged in the appetite may be stimulated and the object of the low-calorie diet defeated. This must be avoided, but this does not mean a program of no activity,

which would also result in putting on weight, as has already been pointed out. A happy medium between these two extremes is that of moderate, regular exercise which does not increase the desire for food but does consume energy. Using such figures as those given on pages 53 and 54 for the energy cost of activities, one can calculate that a man, weighing 194 pounds, who walked one hour each day for one year at the moderate rate of 3 miles per hour would expend the energy equivalent of 15.5 pounds of fat, and this would mean that much loss of body weight. In the light of our present-day knowledge of obesity, the best program for reducing weight is the combination of a low-calorie diet adequate in all other respects with regular, moderate exercise.

Obesity in the Young

Obesity is not characteristic of youth. Under twenty-five years of age the natural tendency is toward under- and not over-nutrition, yet a few children are overweight for height and age. Sometimes this is because they are lazy and overfed; increasing their activity and curtailing sweets (usually the cause of surplus of calories in such cases) will bring them to a better condition. In a survey of children in Boston it was found that the obese children, on the average, did not eat more than the controls (normal weight children) but were much less active. Sometimes overweight, if not extreme, in the period preceding adolescence may actually be an advantage, since often the extra weight is rapidly outgrown in the sudden increase in height which commonly occurs at puberty. There is, however, a type of obesity of which the fat boy in Dickens' *Pickwick Papers* is an example. "The fat boy rose, opened his eyes, swallowed the huge piece of pie he had been in the act of masticating when he last fell asleep, and slowly obeyed his master's orders." Here are all the conditions for fat storage—a good appetite, movement reduced to a minimum, and a pathological metabolism attested by the chronic somnolence—"He's always asleep, goes on errands fast asleep and snores as he waits on the table." This is a comparatively rare type of endocrine disturbance in which structures in the brain and possibly the posterior lobe of the pituitary gland play a part. Such a case should be referred to an expert in endocrinology. Bruch, Kerley and Lorenze, and Schlutz all report that in their experience as pediatricians they find relatively few cases of obesity due to any pathological disturbance

and that, therefore, endocrine treatment is rarely needed. They find adjustment of intake to output of calories all that is required in the large majority of their cases, just as is the case with adults.

Obesity is a handicap to children, because they do not fit well into the regular athletic and play program and are more liable to accidents and strains. Veeder, from a four-year study of 200 private school boys ranging from nine to seventeen years of age, calls the overweight boy as much of a problem as the underweight. "The fat boy is too heavy to fit in with hard exercise or play, such as football, with boys of his own class and age, and too young and immature to play with boys of his own weight but older in years and stronger. In games requiring more skill, such as baseball and tennis, they are decidedly awkward and backward as a group and hence we find them with the tendency to withdraw from competitive play and loaf, with the result that these overweight boys, who are in particular need of exercise, are the ones who have to be continually driven and supervised." ¹⁰

Ordinarily the basal metabolism of overweight children is within the normal range. Mulier and Topper of the Pediatric Service of Mount Sinai Hospital, New York City, in a study of 78 boys and girls from fourteen to sixteen years old, found this to be true in about three-fourths of the cases, and in another study of 25 boys and girls between five and fourteen years of age, they could find no evidence of any endocrine disturbance, though the children were from 20 to 76 per cent overweight. The basal metabolisms were high normals or above. In every case there was a history of overfeeding. Many had voracious appetites so that the total calorie intake was in some instances twice as much as needed. The diets were rich in carbohydrates and fats, with very little in the way of vegetables or fruits.

Treatment consisted in careful regulation of the total calories, care being taken to select foods which would keep the quantities of protein, the various mineral elements, and the vitamins up to the appropriate amounts for children of their ages. Active physical exercise, such as walking, roller skating, tennis, handball, and swimming, was also prescribed. Under this regimen for about four and a half months the children's weekly average loss was three-quarters of a pound and their gain in height above expectation. Furthermore they acquired a

¹⁰ Veeder, B. S. "The Overweight Child." *Journal of the American Medical Association*, Vol. 83, page 487 (1924).

feeling of well-being, an increased capacity for physical activity, an increased interest in all school activities, and greatly improved eating habits, with a loss of their passion for food.¹¹

It does not seem wise to reduce the weight of a growing child except under medical supervision, but it may be possible to hold his weight stationary until by a carefully regulated diet and by suitably planned exercise he has lowered his excess of fat. As a rule, children do not enjoy being obese and are willing to cooperate in measures to bring their weight to normal, but care must be given to them over a long period of time. Children easily learn to count their own calories and can thus help themselves. It is important to see that each such child gets as a part of his ration a minimum of three glasses of milk and one egg daily, at least 300 calories of whole wheat bread and potatoes together, citrus fruit and some vegetable other than potatoes, at least one teaspoonful of cod liver oil or its equivalent in capsule form daily, no candy, cake, preserves, syrups, soft drinks, etc., and nothing whatsoever between meals except plenty of water.

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¹¹ Mulier, H., and Topper, A. "Treatment of Obesity in a Group of Children." *American Journal of Diseases of Children*, Vol. 47, page 25 (1934).

Water

Section 1. WATER AS BODY-BUILDING MATERIAL

When a rubber water bottle is full of water, one is quite well aware that the water is there, even though the stopper holds every drop inside and the outside is perfectly dry; but how many realize that a potato skin, neatly incasing the useful tuber in a dry covering, also holds water like the rubber bottle? In contrast to the example of the rubber bottle, we do not realize that there is water in the potato because it is held in the cells; but when we break the cell walls, as

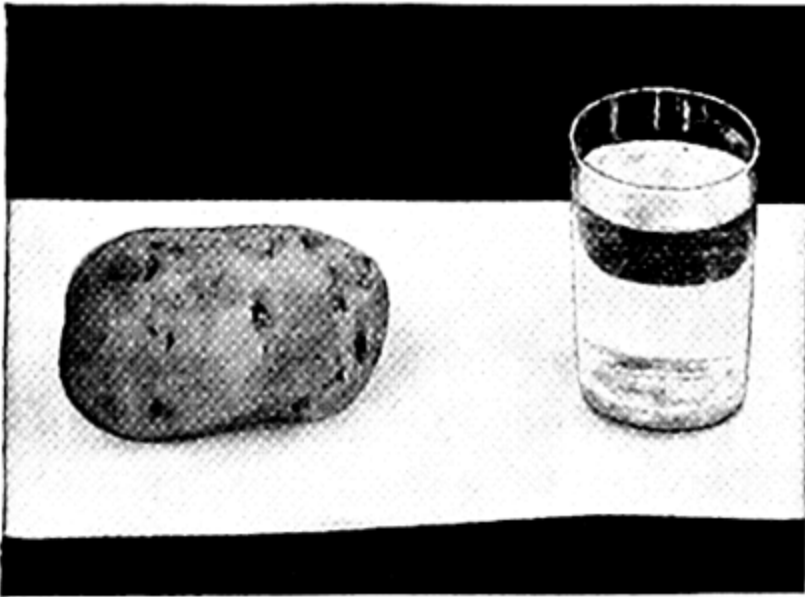


Fig. 31. A Half-Pound Potato Contains Nearly a Tumblerful of Water

in grating a raw potato, we can squeeze out a surprising amount of water (see Fig. 31). It is the same with the body of a man. Muscles, liver, and kidney hold as much water in proportion to their weight as does the potato; brain tissue holds more; and even bone, proverbially dry, is more than one-third water. All together, two-thirds of the adult human body is water.

Water is essential to the constitution of protoplasm. No cell functions when it is absolutely dry, and most cells must be constantly bathed with fluid, in order to do their work. Furthermore, the cells depend upon having their food transported to them by the water route (the blood), a demand which alone requires about 10 pounds of water constantly in circulation.

The cells also depend upon having their waste products flushed away, so there must be waste-bearing water (urine) while there is life. The surface of the lungs must be kept moist or there can be no intake of oxygen or riddance of carbon dioxide.

Water is so commonly taken in response to the feeling of thirst that we ordinarily think little about our water supply, save to be sure that it is sanitary and refreshing. But we also get more or less water in food, as even the driest cracker is not absolutely water-free. The amounts in some common foods are indicated in Figs. 32 and 33.¹

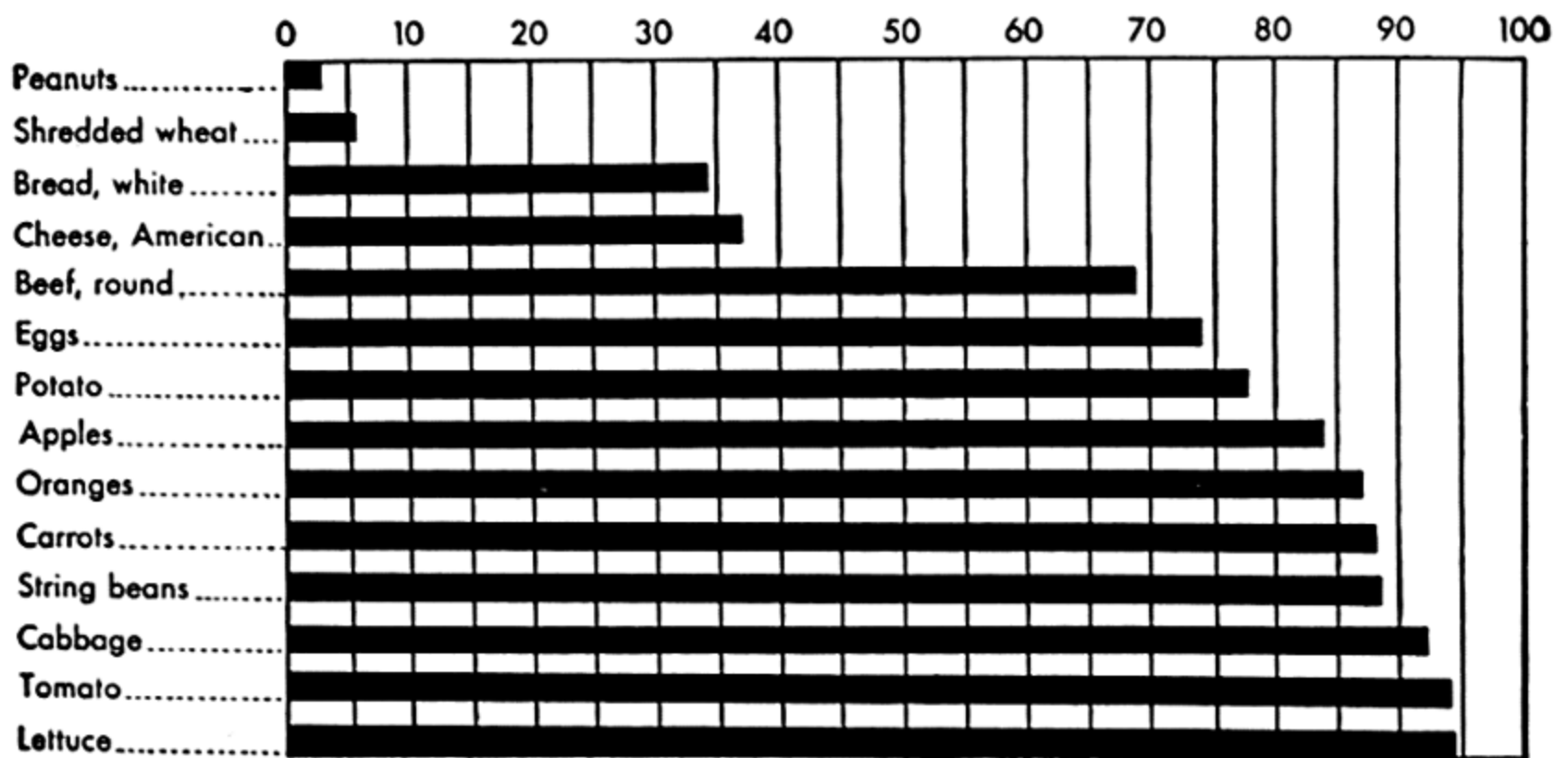


Fig. 32. A Comparison of the Water in Some Common Foods in Per Cents

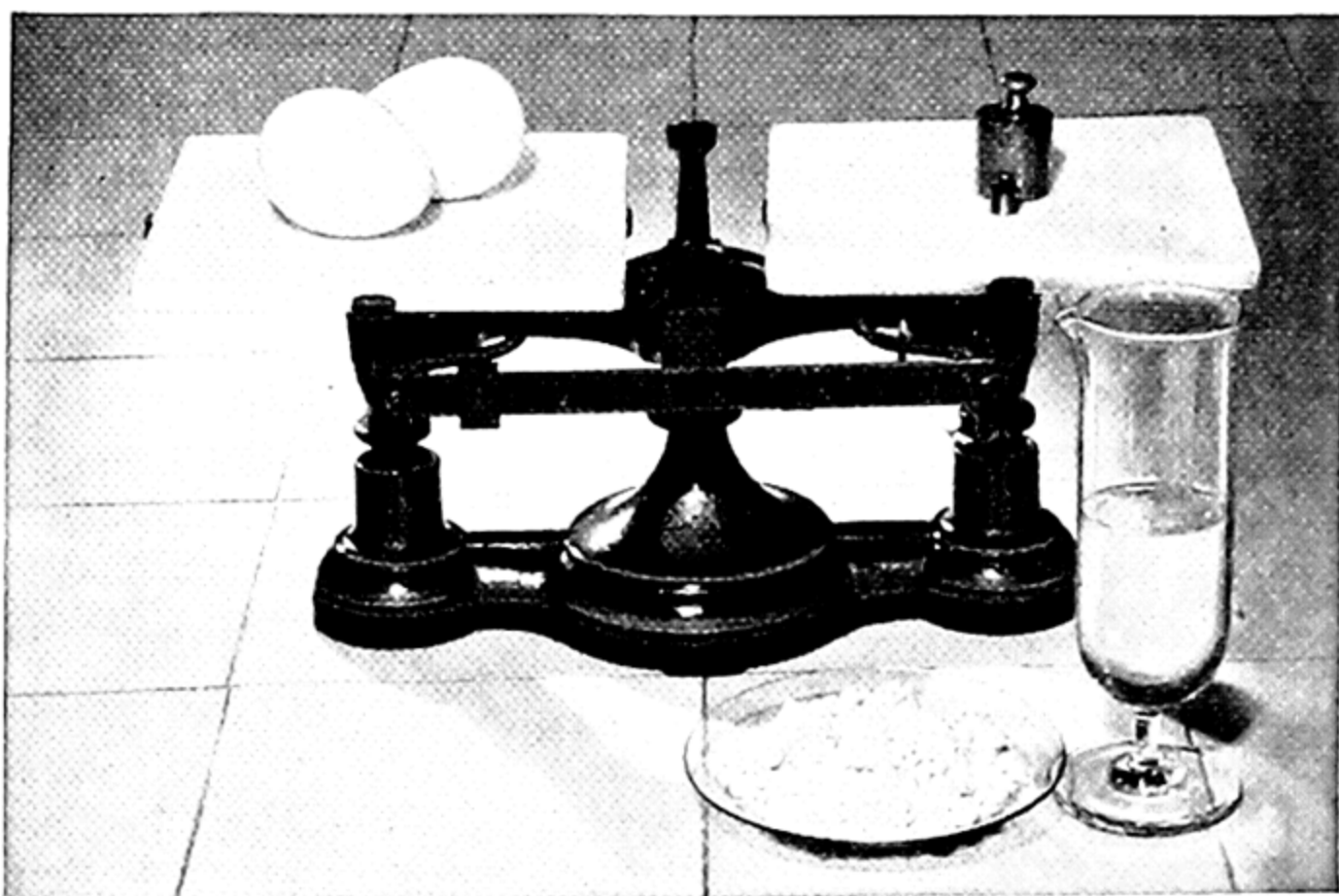
A certain amount of water is produced within the body by the combustion of the fuel foods. A similar production of water may easily be demonstrated by setting a cold flat iron on a gas burner. Before the flame has had time to warm the iron the water of combustion from the burning gas condenses on the iron, often making it perceptibly wet. Later on, the heat of the iron converts the water into vapor and it is no longer perceived. So in the body, the oxidation of 100 grams of fat results in the production of 107 grams of water, and the oxidation of 100 grams of protein, of 41 grams of water. Benedict calculated that Levanzin, the subject of the 31-day fast, produced on the twenty-first day by combustion of his own body substance 341 grams of water. This metabolic water is useful for the

¹ For amounts in other foods, see Table 1, Agriculture Handbook No. 8, *Composition of Foods—Raw, Processed, Prepared*. U.S. Department of Agriculture (1950).

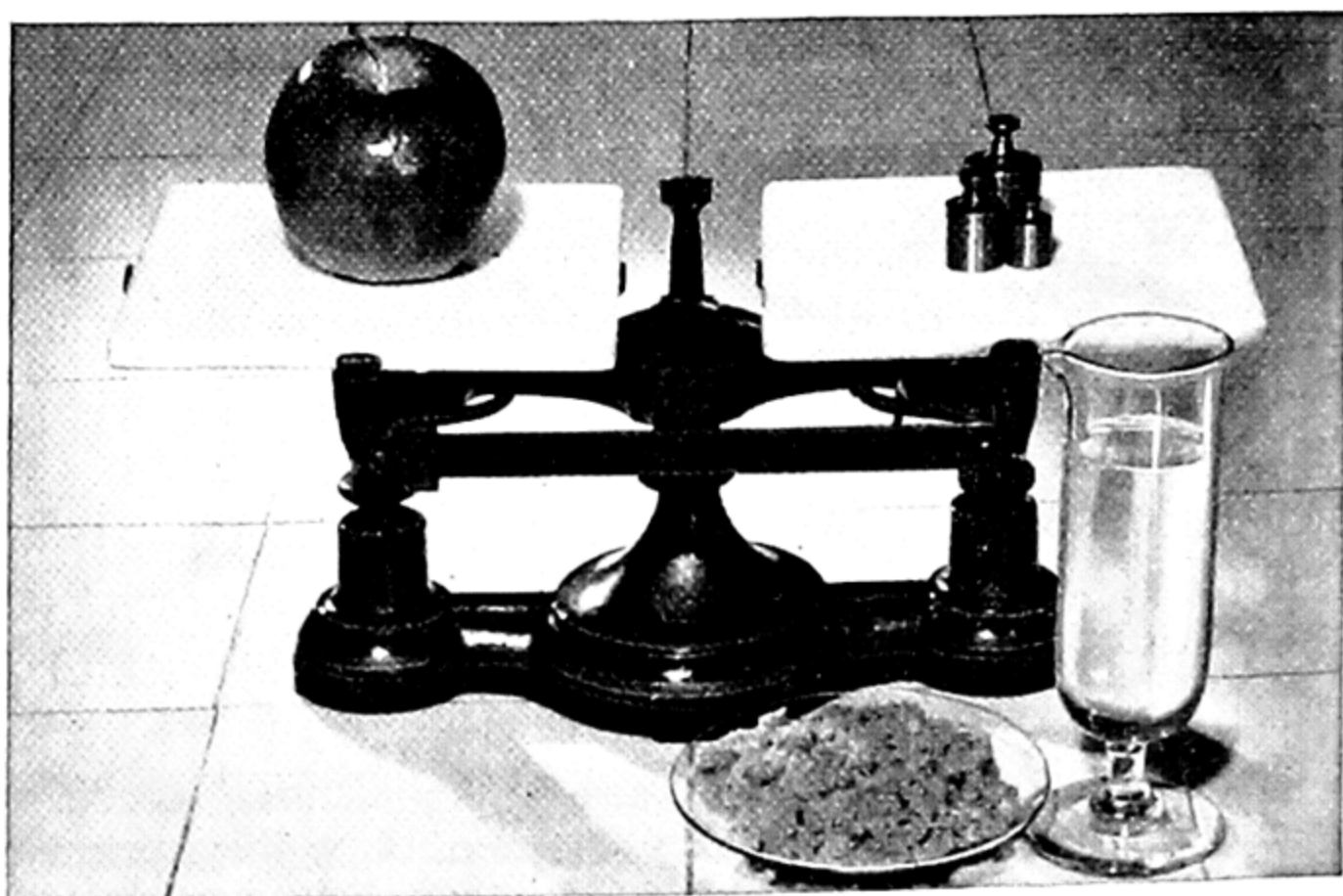
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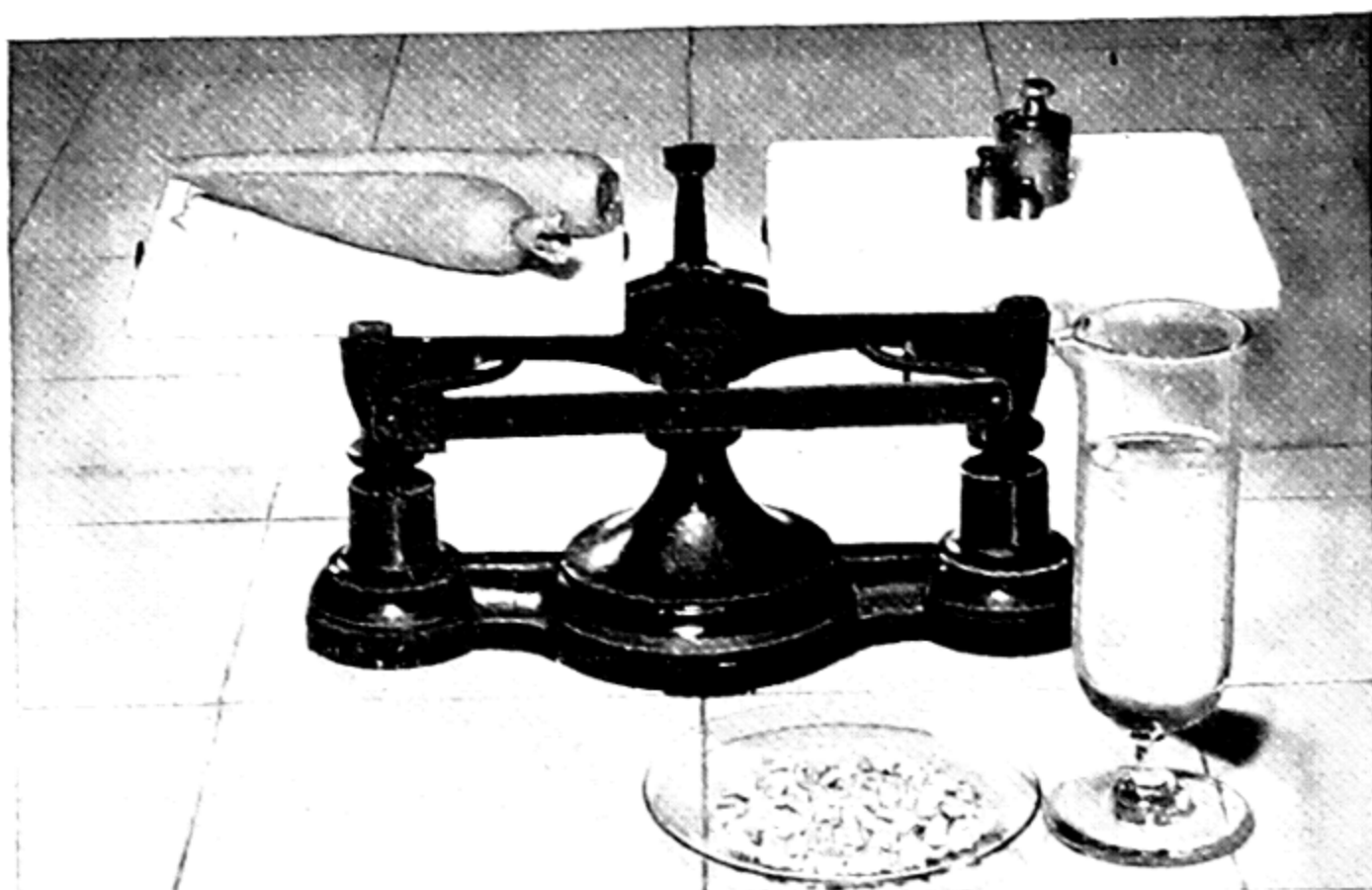
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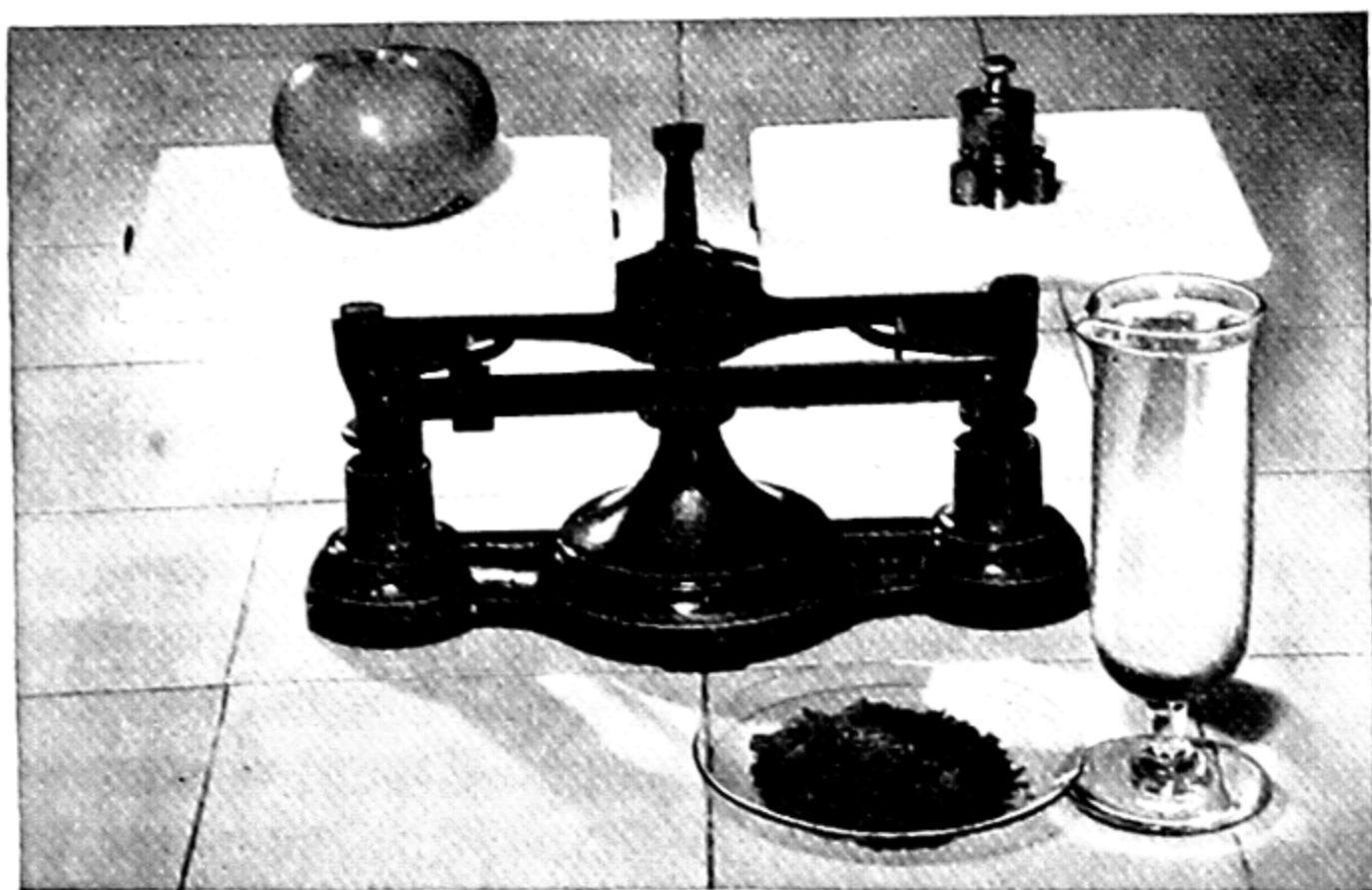


Fig. 33. Comparisons of Fresh and Dehydrated Foods

<i>Food</i>	<i>Fresh</i>		<i>Dehydrated</i>		<i>Water</i>	
	<i>Measure</i>	<i>Grams</i>	<i>Measure</i>	<i>Grams</i>	<i>Measure</i>	<i>Grams</i>
Milk	1 cup	244	$\frac{1}{3}$ cup	32	$\frac{7}{8}$ cup	212
Eggs	2 medium	108 A.P.	$\frac{1}{4}$ cup	28	$\frac{3}{8}$ cup	80
Apple	1 medium	150 A.P.	$\frac{1}{2}$ cup	24	$\frac{1}{2}$ cup	126
Carrots	2 medium	125 A.P.	$\frac{1}{4}$ cup	15	$\frac{1}{2}$ cup	110
Tomato	1 medium	165 A.P.	$1\frac{3}{4}$ tbsp.	10	$\frac{3}{4}$ cup	155

distribution of nutrients, making changes in concentration within the cell which facilitate movement of substances into the cell.

Many varieties of insects have nearly all their water needs met by this metabolic water, subsisting on food containing less than 10 per cent of water and never taking a drink. For animals in hibernation, it is sufficient for several months. Dogs have not as high water loss as man because they do not perspire.

DuBois found the loss of water from lungs and skin in the normal resting man to be 700 to 1,000 grams per day, at a temperature of 23° C. (73.4° F.) and medium humidity. Benedict and Milner accounted for the water intake and output of a man for a day as follows:

<i>Intake</i>		<i>Output</i>	
Drink	1,950.00 grams	Feces	191.30 grams
Food	2,972.43 "	Urine	1,089.20 "
		Respiration and perspiration	3,929.73 "
<hr/>		<hr/>	
4,922.43 grams		5,210.23 grams	

The water content of the body is subject to considerable fluctuation. Benedict and Joslin reported a marathon runner who lost 8.5 pounds in three hours and a football player who lost 14 pounds in one hour and ten minutes, of which 13.75 pounds were calculated to be water. Not only "sweating out" but also certain changes in diet affect the water content of the body; for example, when the body changes from a strictly carbohydrate diet to one of fat or protein exclusively there is a considerable loss of water which will be regained upon resumption of the carbohydrate diet.

There are, then, three important sources of body water:

- (1) Water taken as a beverage or in other liquids.
- (2) Water contained in solid foods, especially fruits and vegetables.

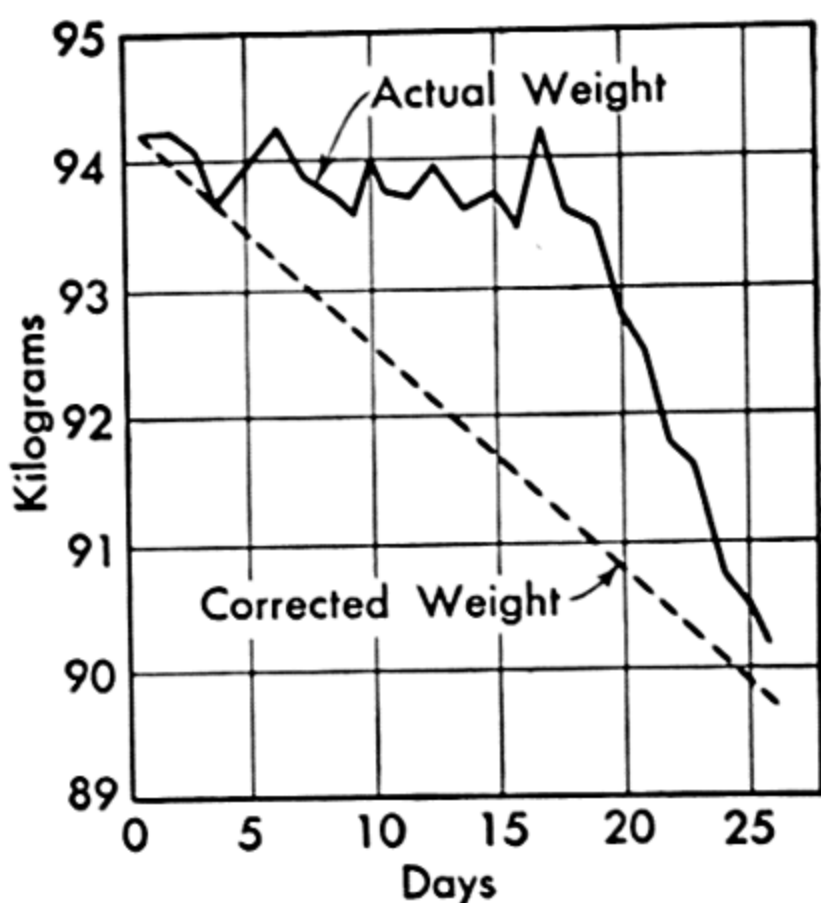
- (3) Water formed in the tissues in combustion of the fuel foods.

The normal avenues for water loss are (1) the skin, (2) the respiratory passages, (3) the alimentary tract, and (4) the kidneys. Any considerable loss or storage of water usually results in a change in body weight. But in undernutrition water may be stored in the tissues in place of fat, and, conversely, in obesity fat may replace water. Hence an underweight person may increase his food intake with real

advantage even though there be no visible gain in weight at first; and an obese person may be disappointed that reduction in food intake does not bring about an immediate loss of weight, owing to the replacement by water of any body fat burned.

An interesting study was reported by Newburgh at the University of Michigan Hospital.² A girl of fourteen who weighed 207 pounds was established in the metabolism laboratory, where no food was available except what was brought to her by the attending nurse. Her daily food allowance was 1,223 calories less than her daily energy output. For over two weeks she showed no loss in weight, although during this time she had burned up, as shown by actual measurement of her energy output, 2,896 grams (over 6 pounds) of her own body substance. As the study progressed, it became evident that during this period she was storing water at the same time that she was burning off superfluous fat. In a second period of ten days, she lost nearly 9 pounds of weight, of which only about $3\frac{1}{2}$ pounds could be accounted for by the calories spent during this time. The rest of the loss was water. Figure 34 shows her actual changes in weight and also what she would have weighed if no extra water had been retained.

In health the water balance is easily maintained by a liberal water intake. In disease the disturbance of the water equilibrium may be serious and call for special measures to bring about normal conditions.



(Courtesy of Dr. L. H. Newburgh)

Fig. 34. The changes in weight of an obese girl on a reducing diet. She retained water for over two weeks, and during this time showed no loss in weight although combustion of body fat was going on all the time. Later the water was excreted and her weight fell. The broken line shows the rate at which loss would have occurred had there been no water retention.

² Newburgh, L. H., and Johnson, M. W. *The Exchange of Energy between Man and the Environment*, page 92. Charles C. Thomas (1930).

Section 2. WATER AS A REGULATOR OF BODY PROCESSES

For the purposes of this section we may advantageously picture the cells of the body as the citizens of a great metropolis. As individuals, each has a private independent life of his own; yet each life is modified by sharing in the activities of some group. Just as citizens come together to work in the same shop or to participate in the enterprises of some club, so cells are massed in tissues and organs to perform some special service impossible to perform alone. Furthermore, in addition to individual and group activities, all share in the larger life of the whole. And just as citizens all over a city use the same water and gas mains, so cells all over the body derive nutriment from the common blood stream and receive oxygen by means of the same respiratory system.

There are found in food certain substances which figure prominently in the coordination of the functions of nerves, glands, muscles, etc., and enable the body to use its available fuel and building material to the best advantage. These regulating substances may be grouped in three main divisions: water, mineral elements, and vitamins. The regulatory functions of water will be discussed in this section.

We have seen in Section 1 that water is an indispensable constituent of body tissues and that even a substance seemingly dry, such as bone, owes more than one-third of its weight to water. Any considerable decrease in the normal amount of water in the body interferes with the manifold physical and chemical processes which are essential to life and health.

Rubner estimated that a man could lose practically all of his stores of glycogen and of fat and even half his protein without serious danger to life, but a loss of 10 per cent of body water is a serious matter and a loss of 20 per cent usually results in death.

The serious conditions brought about by severe and protracted vomiting or diarrhea, or by fever, are partly due to dehydration. Infants with nutritional disorders may lose water from the body to such an extent that the flow of digestive secretions is reduced and the condition of the intestinal tract altered, with the result that food

cannot be digested and absorbed, and feeding does no good until some means are found to restore the lost water to the tissues. Experimentally it has been shown that a dog fed a water-free diet of dried meat and fat lost as much as 20 per cent of the water of his muscles in a few days and the food was regularly vomited because of the changes induced in the alimentary tract.

As has been said, certain insects can subsist upon food materials containing less than 10 per cent of water, i.e., as dry as a cracker, but they have a high energy metabolism and produce within their own bodies, through the combustion of their fuel foods, so-called metabolic water sufficient for their needs. Another interesting instance of meeting the body need for water by internal production is furnished by the camel, which, according to Babcock,³ can go for long periods without drinking, more because of the fat of its hump and its carbohydrate food than because of the water in its stomach, the water formed in the process of food combustion being unusually well conserved by the coat of fine hair which reduces evaporation from the skin. Man, however, and most other large animals which excrete the nitrogenous products of their protein metabolism as urea, require a liberal supply of drinking water in addition to whatever they may acquire by metabolism or in food, to keep the urea content of blood and urine at a low concentration favorable to its excretion.

We must think of water in circulation as one of the conditions of health. Whatever its source, it is carried about and does its work without being chemically altered, again leaving the body as water, by way of kidneys, lungs, skin, and bowels. If we do not drink enough to make good the water loss the body soon ceases to function properly. Hawk states that in his laboratory normal young men put on a very low water ration soon gave evidence of abnormal function as shown by headaches, nervousness, loss of appetite, digestive disturbances, and inability to concentrate on their work, symptoms which were promptly relieved by increased water intake.

Similar symptoms were found among the troops stationed in the arctic regions during World War II where, because of the extreme cold and the amount of fuel needed to melt ice or snow, it was diffi-

³ For an excellent discussion of metabolic water, see Babcock, S. M. *Metabolic Water*. Wisconsin Agricultural Experiment Station, Research Bulletin No. 22 (1912).

cult to obtain enough water to maintain a positive water balance. Chronic thirst, sullenness, and a change in disposition were also noted which affected the discipline.

Hawk made an extensive investigation of the effect of water upon the digestive process in normal individuals, and found that water stimulated the gastric glands to greater activity and improved digestion, while the dilution of the contents of the intestine by a liberal water intake facilitated the absorption of the digested food. He concluded: "The average normal individual will find that the drinking of a reasonable volume of water with meals will promote the secretion and activity of the digestive juices and the digestion and absorption of the ingested food, and will retard the growth of intestinal bacteria and lessen the extent of the putrefactive processes in the intestine."⁴

Section 3. REQUIREMENT

In the 1953 recommendations of the Food and Nutrition Board of the National Research Council the daily allowance of water suggested for adults is 2.5 liters (10 to 11 glasses). Much of this is provided in prepared foods. Water taken freely is desirable for optimum health of both adults and children and thirst can usually be depended upon as a guide. However, with extreme heat and excessive sweating thirst may not keep up with the actual water requirements and forced intakes of as much as four glasses per hour for a short time may be necessary.

Circulation of water is also essential to the elimination of waste from the body, and the freer this circulation the more readily are injurious products removed. It is better to have dilute than concentrated urine, both for the sake of the urinary tract itself and for the organism as a whole.

Of purely regulatory functions attributable to water the most conspicuous is related to the control of body temperature. The pathway for heat loss varies with the temperature of the environment; at low temperature there is little evaporation of water, but when the temperature of the air approximates or exceeds body temperature water evaporation must remove all the excess heat. In the normal resting man, at a temperature of 23° C. (73.4° F.) and medium humidity,

⁴ Hawk, P. B. "Water as a Dietary Constituent." Barker's *Endocrinology and Metabolism*, Vol. 3, page 294. D. Appleton and Co. (1922).

about one-fourth of the calories of the basal metabolism are dissipated through the evaporation of water as insensible perspiration and moisture from the lungs. Sweating promotes heat loss through evaporation if environmental conditions permit, and also favors conduction and radiation by increasing the moisture of the skin and perhaps of clothing. In a hot, dry atmosphere, the amount of water lost as perspiration is enormous. On the other hand, at a low temperature, sweating not only ceases but there is an actual mobilization of water from the blood into the tissues, so that less of it shall be brought to the surface to suffer cooling; thus the body heat is conserved.

Cannon sums up the case for water thus: "Water is the vehicle for food materials absorbed from the digestive canal; it is the medium in which the chemical changes take place that underlie most of our obvious activities; it is essential in the regulation of body temperature, and it plays an important part in mechanical services such as the lubrication of moving parts in the sliding of the intestinal coils on one another and the slipping of joint surfaces to and fro." ⁵

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⁵ Cannon, W. B. *Wisdom of the Body*, revised edition, page 77. W. W. Norton and Co. (1939).

Protein

The Essentials for Body Building

The beginning of a human being is an egg too tiny to be studied with the naked eye. Initiated by the union of sperm and ovum, a complicated system of chemical processes which we call life at once enables the minute organism to take up materials from its environment for its own growth. During its prenatal life the human fetus increases its weight more than five million times. By the fourth month of intrauterine life it may have attained a weight of 36 grams; at birth it will have increased this latter weight one hundred times. Even after birth the increase in substance is great. A newborn baby weighs on the average from 7 to 7.5 pounds; the adult into which he grows may weigh twenty to thirty times as much. The calories represented in the body of a four-month fetus are about 10; in the infant at term, about 4,000; in the average adult man, over 50,000 from protein alone and probably half as much more from fat and glycogen. The major portion of the energy-yielding materials ingested must be spent in the maintenance of internal and external activity, but a certain part must also be retained for growth. Up to the time of birth the human fetus stores daily an average of at least 3 grams of protein and 8 grams of fat. An infant ingesting 520 calories and gaining 3 grams of protein and 3 grams of fat in a day will have stored 39 calories, or $7\frac{1}{2}$ per cent of the total calories eaten.

Protein is an essential component of every living cell in the body and makes up a large part of the solids of a muscle cell; a small portion of the fat enters into the composition of nervous tissue; the rest is stored as adipose tissue. We also find carbohydrates in the living body, not only as a source of energy but as constituents of certain indispensable proteins and certain other compounds found in

the brain and nerves. Even starvation does not deprive the blood of all its sugar nor the liver of all its glycogen.

Thus from the stream of energy-yielding proteins, fats, and carbohydrates continually passing through the body as we eat, digest, and assimilate our food, materials for constructive purposes are withdrawn as needed. Similarly water, whose constant flow through the body is one of the conditions of life, as has already been pointed out, is an essential part of the body structure.

In addition to proteins, fats, carbohydrates, and water, we find in the body an assortment of mineral elements and vitamins. Equally important with the supply of energy is the supply of each mineral element and each vitamin in the amount needed. A shortage of any one, no matter how minute the daily requirement, will interfere with normal nutrition. Only when each essential is properly represented can the body maintain its health, replace worn-out parts, and construct new materials in the process of growth.

Protein as a Source of Energy

Muscular work is done preferably and most economically at the expense of carbohydrate food. Mixtures of fat and carbohydrate in which carbohydrate predominates are burned with practically the same ease as pure carbohydrate. Fat alone is utilized with less ease than a mixture of the two and with a loss of from 8 to 12 per cent of its energy value. Protein can be economically used when a small proportion is mixed with carbohydrate or carbohydrate and fat, but when taken as the sole source of energy, it is burned at a rate that is wasteful in the extreme, the loss amounting to at least 30 per cent. As long as carbohydrate and fat are available, muscular work is not done at the expense of the protein supply.

In the absence of other sources of fuel it is possible for muscular work to be done exclusively at the expense of protein. However, the protein so used is first deprived of its nitrogen and thus put on a par, so to speak, with the other fuel foods, carbohydrate and fat. It is as if one should undertake to make a fire with boards full of nails. The boards would burn like any others, but the nails would add nothing to the fire.

Bischoff and Voit (1860) fed meat to dogs under a variety of conditions, collecting and analyzing the urine, and found¹ that the more protein the dog ate the more nitrogen there was in the urine,

thus demonstrating that it was the character of the diet rather than the amount of muscular work which caused changes in the protein metabolism. This concept was put to the test in 1860 by two of Voit's pupils, Fick and Wislicenus. They undertook to discover just how much protein was used in a strenuous excursion up the Faulhorn, a mountain over 6,000 feet high, and demonstrated conclusively that muscular work is done almost entirely at the expense of carbohydrate and fat when these are available. Eating only nonnitrogenous food and keeping account of all nitrogen excreted in the mountain adventure, these young men compared the amount of protein metabolized with the work actually done and found that less than half the fuel burned was derived from protein.

Years later a far more accurate experiment of Atwater's showed more clearly the influence of work on nitrogen excretion. Several persons were studied in the respiration calorimeter for many days, first at rest and then at work. In the rest experiments they metabolized 1.51 grams of protein per kilogram; when they worked hard enough to double their energy expenditure they did not raise their nitrogen output at all, as it averaged 1.49 grams per kilogram. Thus it is clear that in severe muscular exercise, the foodstuff needed to prevent exhaustion is not protein but carbohydrate.

When protein is used as fuel, the nitrogen which it contains is not an asset but a liability, which must be gotten rid of as speedily as possible. The protein is transformed within the body into simpler compounds and the nitrogen is excreted in the urine, chiefly in the form of urea, together with a relatively small amount of ammonia. Then the simpler compounds, free of nitrogen, are burned to carbon dioxide and water.

Protein as Body-Building Material

When protein is used as building material the story differs greatly from that when it serves as body fuel. As body-building material the nitrogen is the prime consideration. Every living cell is continually demanding it for upkeep, working it over into living tissue, or using it for the construction of hormones, enzymes, antibodies, and other body regulators, and ultimately discarding it again in the form of simpler compounds (chiefly uric acid from all kinds of active cells and creatinine from muscle cells) which are excreted in the urine. There is thus a maintenance requirement for protein, which continues throughout life and is independent of muscular activity.

Proteins are essential constituents of both the nucleus and the protoplasm of the cells and are the chief organic constituents of the muscle and glandular tissues of the body. They exist in many forms. More recent investigations using radioactive compounds have shown that protein exists in a dynamic state and that the old idea of a more or less static state of body protein and protein synthesis in the adult as being restricted to "wear and tear" of metabolism is no longer tenable. Most protein tissues are constantly undergoing degradation and synthesis. In the liver, for example, it has been found that more than half of the protein may be broken down and resynthesized within ten days. There is a ready interchange in both directions between plasma proteins and hemoglobin and between tissue proteins and plasma proteins.

In protein deficiency the body stores of protein as well as the plasma protein may be drawn upon for metabolic needs. In youth, the process of growth requires additional protein for the building of new body substance. This growth requirement makes the total protein requirement of childhood higher in proportion to size than that of the adult. Only under certain circumstances do we have in adult life a growth requirement superimposed on the maintenance requirement. These are chiefly:

- (1) In athletic training, when muscles increase in size.
- (2) After a wasting disease, when muscles are regaining substance lost.
- (3) In pregnancy, owing to the growth of the unborn child and to some development of the maternal organism.

Protein as a Source of Amino Acids

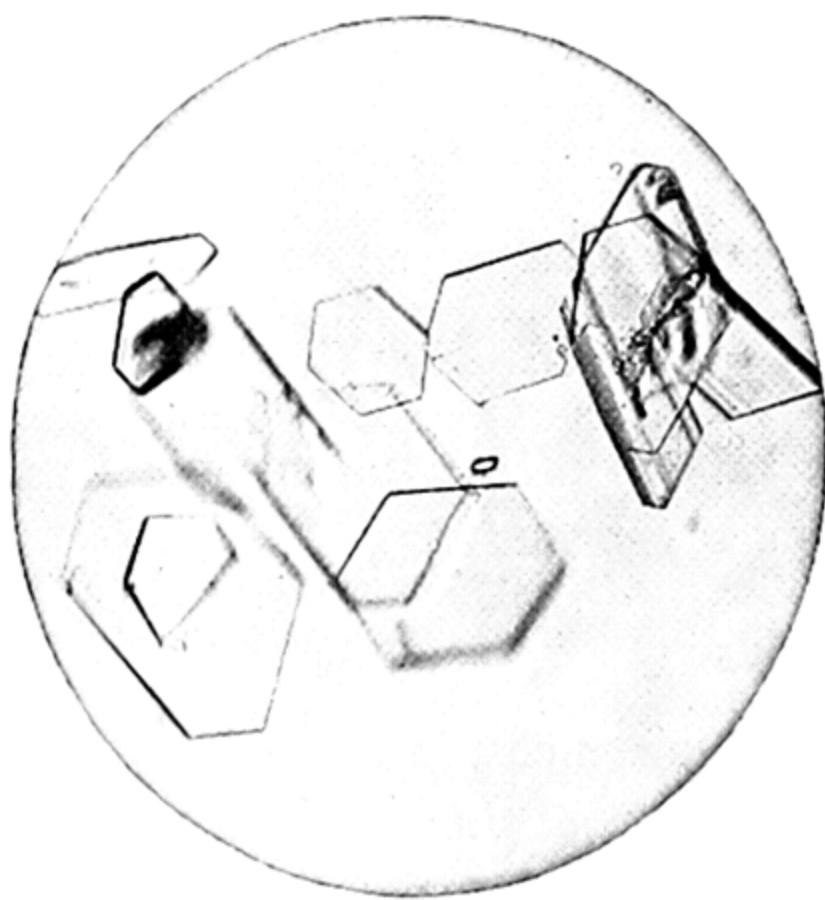
In order to understand protein requirements and how to meet them, it is necessary to know something about the chemical structure of protein itself. Mulder, in 1838, was the first to recognize a nitrogenous material as a fundamental constituent of tissue substance. He named this material "protein," a term derived from the Greek verb meaning "to take first place." The plural form, proteins, is a term which is used as a group name and covers a large number of related nitrogenous compounds. These compounds are made up of simpler nitrogen-containing substances, called amino acids. Twenty-two of these amino acids have been found in food and body proteins, all having certain characteristics in common, but each one exhibiting properties which mark it as a distinct chemical entity. Proteins differ

in the actual number of amino acids present, but most proteins contain between 15 and 20 occurring in many different proportions and combinations.

It was not until about 1900 that a real interest was developed in the amino acids making up these compounds. Prior to this time no quantitative data existed concerning the distribution of amino acids in proteins from different sources, and actually only 12 of those now recognized as constituents of proteins had been discovered. From this meager beginning a vast amount of research on protein and amino acids has been reported during the past half century.

Recognizing the special value of casein, the chief protein of milk, Dr. W. C. Rose of the University of Illinois set out to discover the amino acid make-up of this paragon of proteins. One by one, amino acids were isolated and identified and various combinations of them tried out on young animals in an attempt to attain the natural mixture in pure casein which would support growth. However, the animals failed to grow on these mixtures showing that some essential amino

acid was still missing. It was not until 1936 that the amino acid, now known as threonine (Fig. 35), was discovered and the mystery solved. By 1937, the long-continued painstaking research finally yielded the information which made it possible to make up the combination of amino acids from casein which would provide for excellent growth in young animals. Interestingly enough, only 10 of the 20 amino acids known to be present in casein were found to be necessary and these have been designated as the essential amino acids. The actual amounts of each



(Courtesy of Dr. William C. Rose and
The Journal of Biological Chemistry)

Fig. 35. Crystals of the Amino Acid Threonine

of these 10 essential amino acids required for growth of the weanling rat were also determined.

W. C. Rose defines an essential or indispensable amino acid as

Protein

“one which cannot be synthesized by the animal organism out of material ordinarily available, at a speed commensurate with the demands for normal growth.” The 10 amino acids known to be essential for growth in the weanling rat are listed below:

Arginine ¹	Methionine
Histidine ¹	Phenylalanine
Isoleucine	Threonine
Leucine	Tryptophan
Lysine	Valine

Experiments with human subjects were started by W. C. Rose in 1942, a large number of individuals participating, and within a period of ten years the evidence was sufficient to show conclusively that only 8 of the above amino acids were essential for the maintenance of nitrogen equilibrium in the human adult. Arginine, although essential for the growth of young animals but not for the maintenance of nitrogen equilibrium in adult animals, was found to be dispensable for the maintenance of nitrogen equilibrium in normal human adults. Histidine was also found to be unessential for the maintenance of nitrogen equilibrium in the human adult. When any one of the 8 essential amino acids was omitted from the experimental diets a negative nitrogen balance resulted, the output of nitrogen exceeding the intake. This was accompanied by a failure of the appetite, nervous irritability, and a feeling of extreme fatigue. These symptoms disappeared when the missing amino acid was again included in the diet. Rose has now recommended daily allowances of each of the essential amino acids which he considers *safe* for normal human adult maintenance. These allowances are tabulated below:

<i>Amino Acid</i>	<i>Grams per Day</i>
Isoleucine	1.4
Leucine	2.2
Lysine	1.6
Methionine	2.2
Phenylalanine	2.2
Threonine	1.0
Tryptophan	0.5
Valine	1.6

¹ Not essential for maintenance of nitrogen equilibrium in the human adult.

The amount recommended by Rose² is twice the minimum amount found to be actually required for his experimental human subjects. This generous allowance provides a desirable margin of safety.

At this point in our discussion it might be of interest to compare the amounts of essential amino acids in two kinds of protein (1) casein from milk and (2) zein from common Indian corn (maize). These amounts expressed in per cent (grams per 100 grams) are listed below:

ESSENTIAL AMINO ACIDS IN TWO KINDS OF PROTEIN^a

<i>Amino Acid</i>	<i>Casein Per Cent</i>	<i>Zein Per Cent</i>
Isoleucine	5.6	5.0
Leucine	9.2	21.1
Lysine	8.2	0.2
Methionine	2.6	1.4
Phenylalanine	4.9	7.3
Threonine	4.8	2.6
Tryptophan	1.2	0.0
Valine	6.9	4.0

^a Horn, Jones, and Blum. U.S. Department of Agriculture, Miscellaneous Publication 696 (1950).

All of the essential amino acids needed for the human adult are found in the casein of milk, but in the zein of corn it will be observed that there is no tryptophan and only an insignificant amount of lysine.

That zein was deficient in these two amino acids was demonstrated in 1915 by Dr. L. B. Mendel of Yale University. He reported studies of the effect on the growth of young animals of feeding each of a number of different proteins. When zein, for example, was fed as the only protein, the young rats not only failed to grow, but lost weight rapidly. If some tryptophan was added, the loss of weight stopped but there was no growth and with the zein plus tryptophan the weight remained practically stationary for about 180 days. When lysine was added, growth started at once as shown in Fig. 36.

Osborne and Mendel also demonstrated that gliadin, one of the proteins of wheat, was deficient in lysine. The poor growth record

² Rose, W. C. et al. "The Role of the Amino Acids in Human Nutrition. XV. Summary and Final Observations." *Journal of Biological Chemistry*, Vol. 217, page 987 (1955).

of an animal maintained on a diet with gliadin as the sole protein, is shown in Fig. 37. When milk, rich in lysine, was added to the diet,

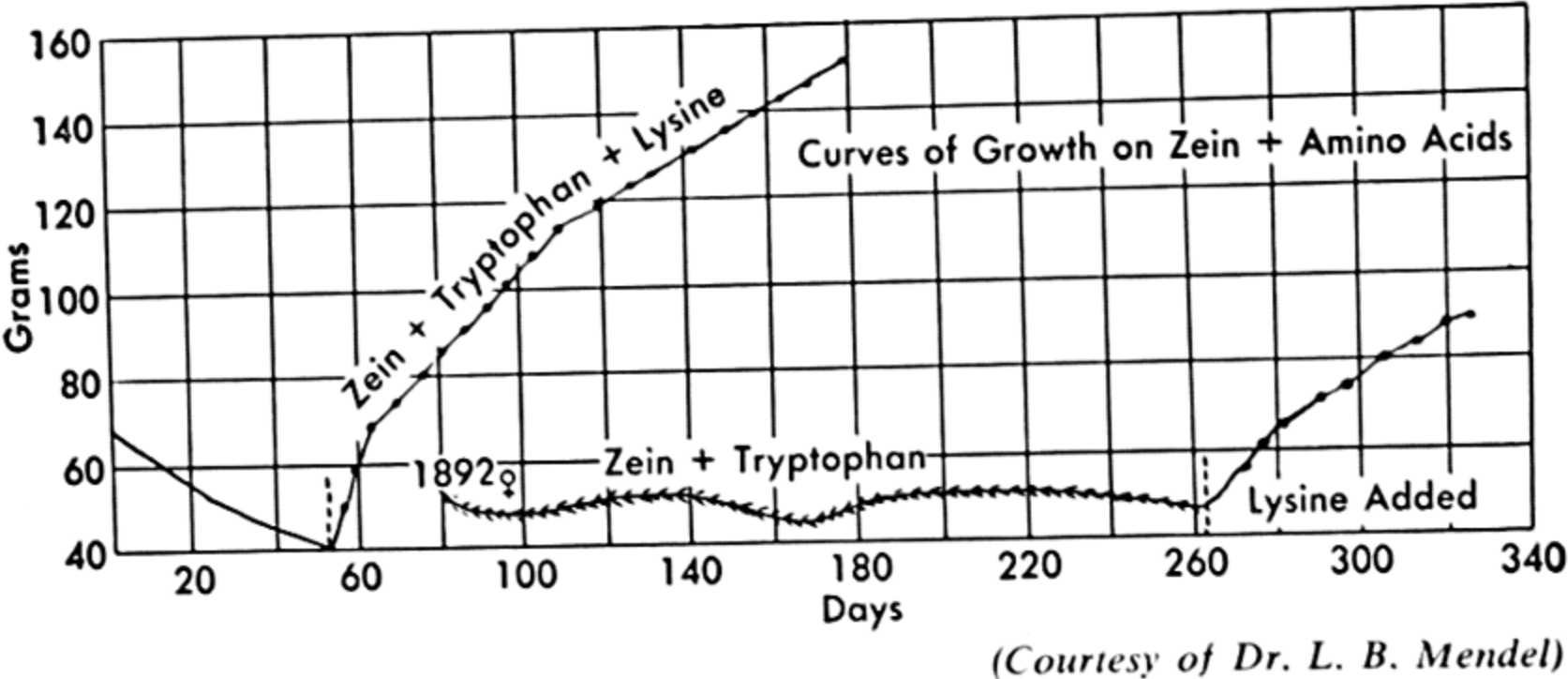


Fig. 36. The solid line shows the decline in weight when zein of maize is the sole protein of an otherwise adequate ration. With zein plus tryptophan weight is maintained, but there is no growth. When lysine is added as well as tryptophan, normal growth is possible.

growth was promptly resumed. When pure lysine was added in place of milk the result was the same. The effect of feeding a lysine-deficient diet to weanling rats, when the diet consisted of zein plus

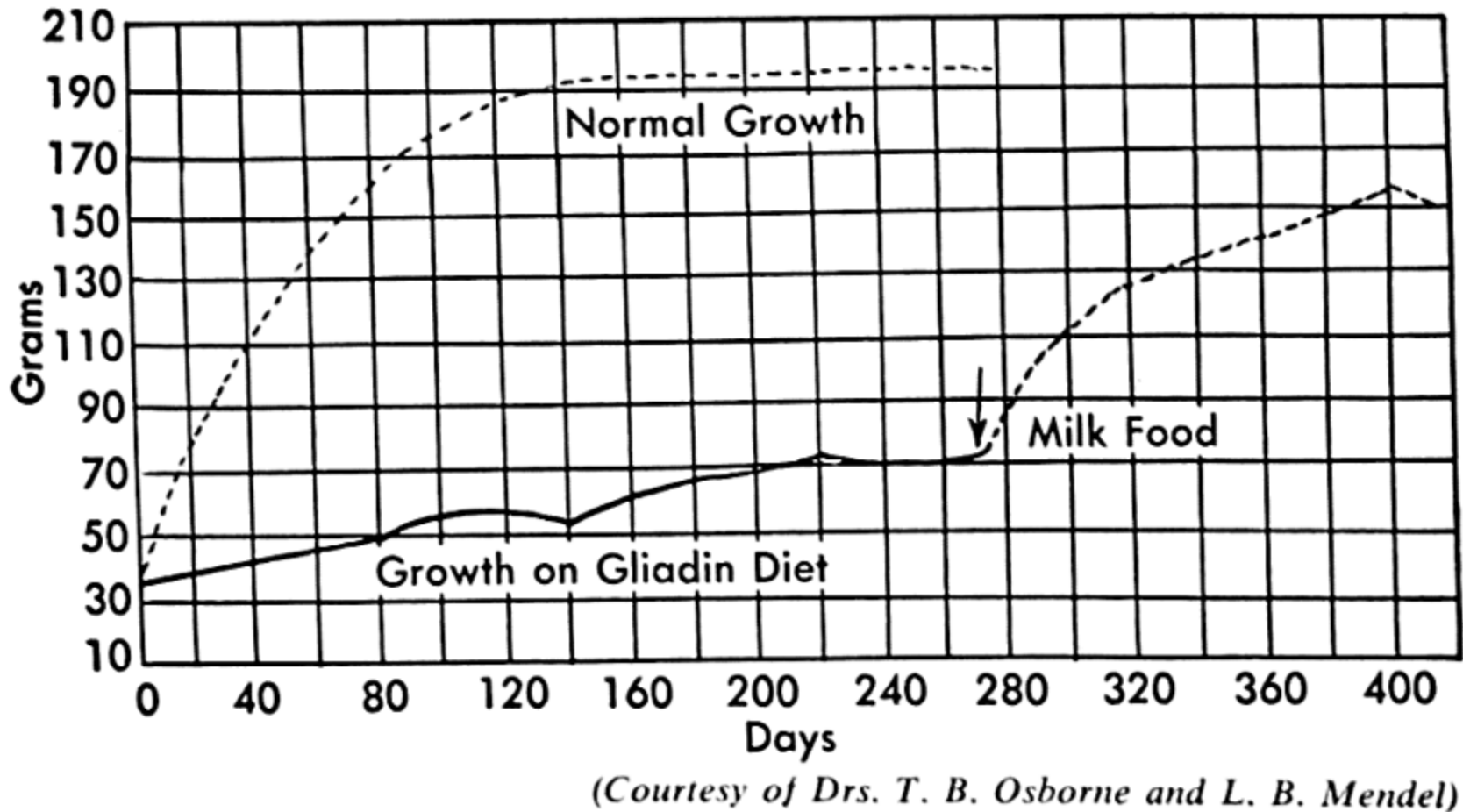
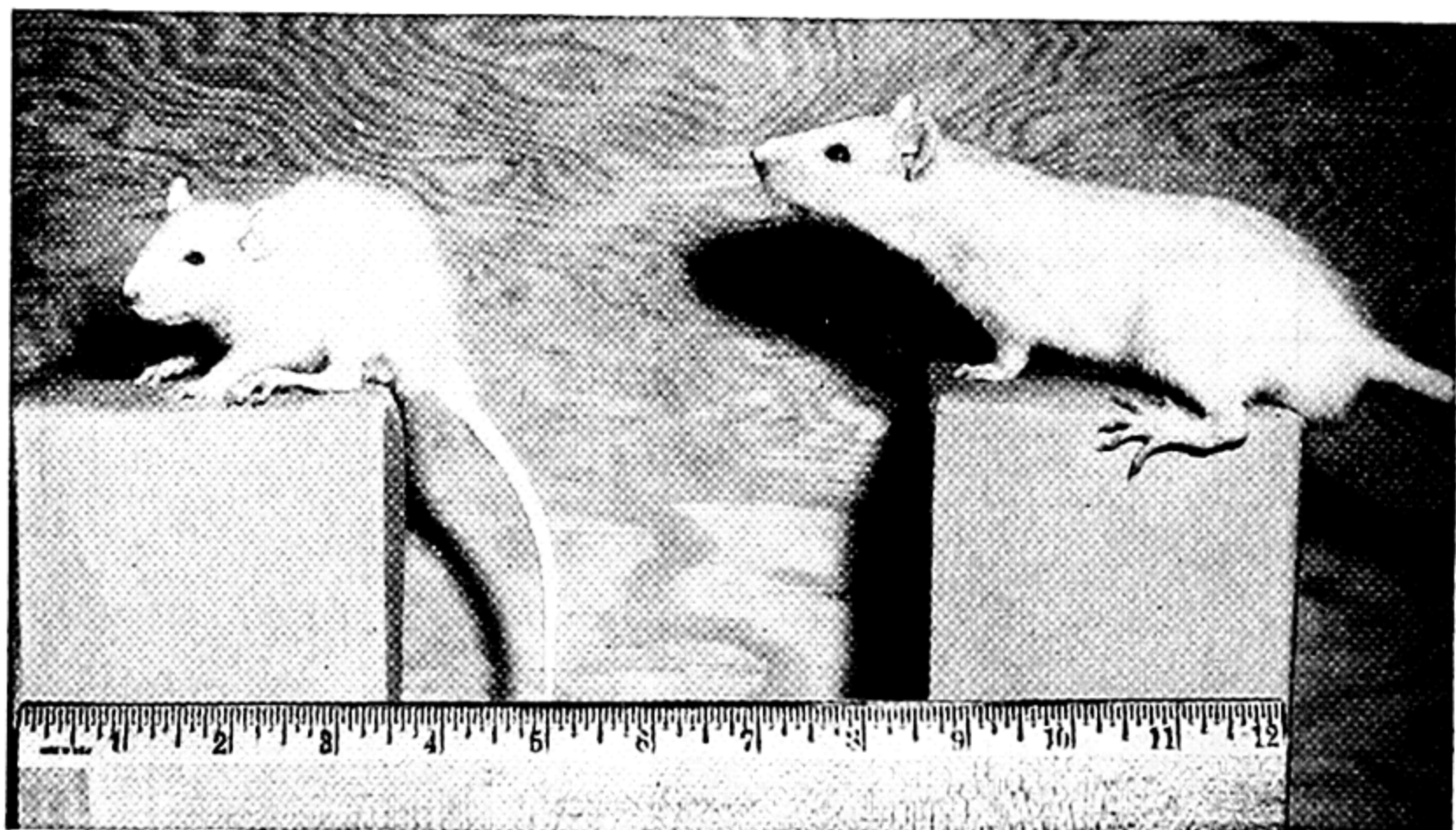


Fig. 37. The growth record of a young rat placed at weaning time upon a diet containing gliadin as the sole protein, and kept on this diet for 276 days. At this time milk food replaced the gliadin food, and the animal was able to grow at a good rate although of an age at which normal rats have usually ceased to grow.

adequate amounts of all other essential amino acids, mineral elements, and vitamins, is shown in Fig. 38.



(Nutrition Laboratory, Teachers College, Columbia University)

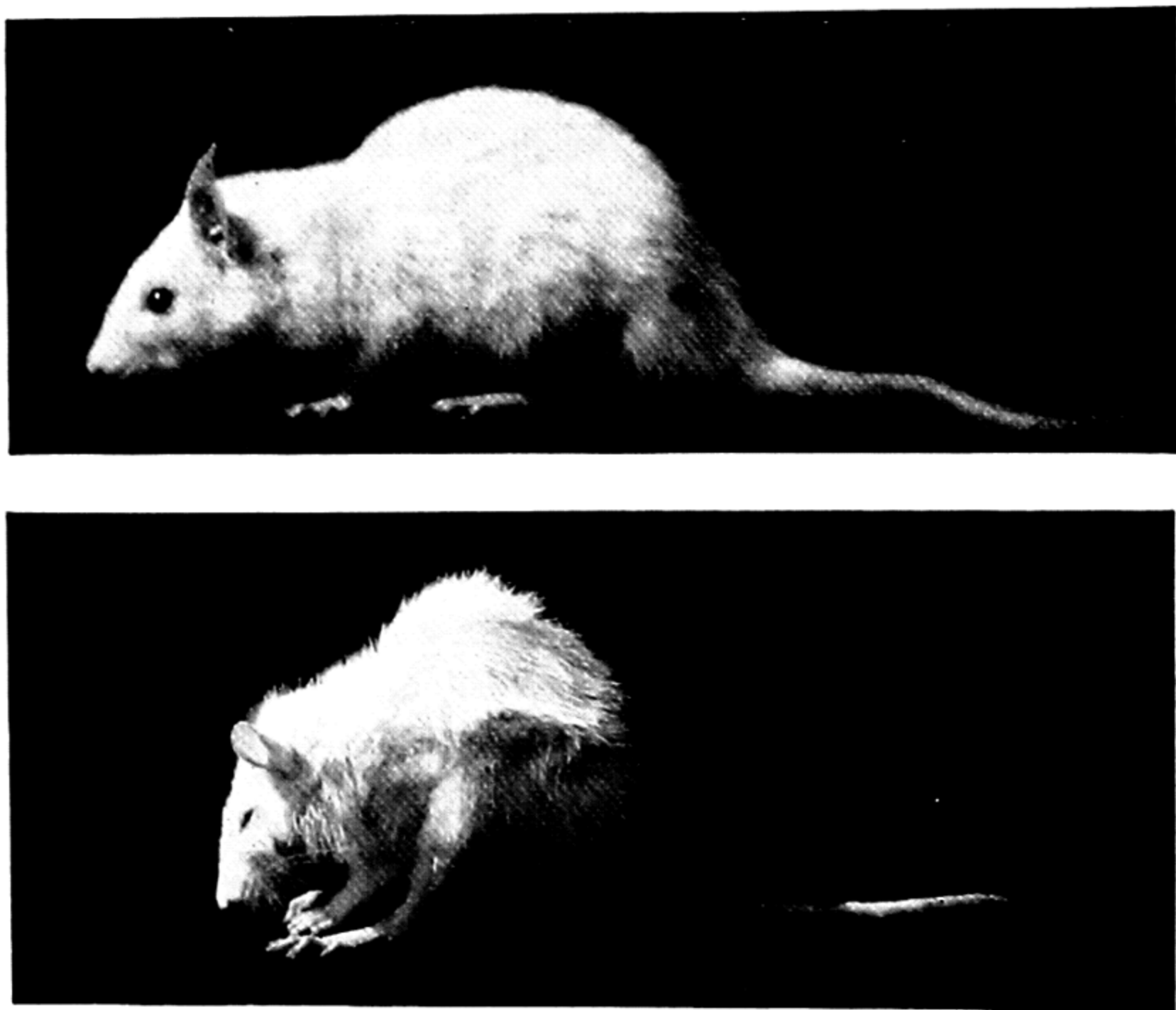
Fig. 38. Effect of Lysine Deficiency on the Growth of the Rat

The animals are the same age and had been on the diets six weeks. The diet of the animal on the right contained zein plus all the amino acids known to be needed by the rat; that of the animal on the left was the same except that lysine was omitted. All essential mineral elements and vitamins were included in the basal diet.

The fact that animals on a diet in which gliadin, low in lysine, is the only source of amino acids will remain in good health over long periods, although stationary in weight, indicates some essential difference between the maintenance of the organism and the construction of new substance. Animals on a diet in which casein is the sole source of amino acids will grow normally if the amount is sufficient but not if it is too small. When the casein is limited to 6 per cent, there will be very little growth, but the animals remain in excellent condition over long periods because all of the essential amino acids are present, though some are in too small amounts to permit growth. On the gliadin diet, no increase in the amount of gliadin will make good the deficiency, since the essential lysine is too low. On the casein diet, it is only necessary to increase the amount of casein to the 18 per cent level to secure excellent growth.

A protein can be resolved into its component amino acids by artificial digestion, and one or more of the amino acids removed.

When histidine is removed from casein in this way and the remainder of the amino acid mixture is fed, not only is the growth of the animals retarded but their health becomes seriously impaired. The result of feeding such a histidine-free diet for 169 days as compared with the result of feeding the same diet plus histidine is shown in Fig. 39.



(Courtesy of Dr. W. C. Rose)

Fig. 39. The upper rat was on a diet adequate in all respects. The lower had a diet similar in every way except that histidine had been removed. Histidine is thus shown to be an indispensable constituent of the diet of the rat.

Food Sources of Essential Amino Acids

Proteins which, when fed as the only protein food, will maintain life and support normal growth are sometimes called “complete.” Those which will maintain life but do not support growth are described as “partially incomplete,” while those which will neither maintain life nor support growth are called “incomplete.” These differences are due to differences in their amino acid make-up.

Proteins of various kinds are associated in many foods. Some foods have very little in proportion to their weight, such as most fruits and vegetables. Others are rich in protein, as eggs, cheese, nuts, and lean meats of all sorts, "fish, flesh, or fowl." Cereals are not very rich in protein, but, because of the relatively large amounts eaten by the human race, they are a source of considerable importance. Among other vegetable foods, the legumes, especially peas, beans, and peanuts, are comparatively high in their yield of protein. Tables giving simply the total amount of protein present tell us nothing, however, about the kinds of protein occurring in the different foods.

The tabulation below shows the chief kinds of protein in some of our common food materials with reference to the nutritive efficiency of their proteins. From this it will be seen that in ordinary daily life in the United States the chances of our getting none but incom-

CHARACTER OF PROTEINS IN SOME COMMON FOODS

<i>Food Materials</i>	<i>Chief Kinds of Protein Present</i>	<i>Complete or Incomplete</i>
Almonds	Excelsin	Complete
Cheese	Casein	Complete
	Lactalbumin	Complete
Corn	Glutelin	Complete
	Zein	Incomplete (lacks lysine and tryptophan)
Eggs	Ovalbumin	Complete
	Ovovitellin	Complete
Gelatin	Gelatin	Incomplete (lacks tryptophan and tyrosine; high in lysine)
Lean meat	Albumin	Complete
	Myosin	Complete
Milk	Casein	Complete
	Lactalbumin	Complete
Navy beans	Phaseolin	Incomplete
Peas	Legumin	Incomplete
Soybeans	Glycinin	Complete
	Legumelin	Incomplete
Wheat	Gliadin	Partially incomplete (low in lysine)
	Glutenin	Complete

Protein

plete proteins are small; in animal food, such as milk, cheese, eggs, and meat, the various proteins present are all complete, but in vegetable foods very commonly an incomplete protein is associated with a complete one; and occasionally, the total protein content is of poor quality. The supplementing value of one protein for another must, however, be kept in mind. The supplementing value of milk is exceedingly high. An instance is furnished by an experiment on growing pigs, in which one lot received protein only in the form of corn, which, as has been noted, contains the incomplete protein zein, which is inadequately compensated for by the complete protein glutelin; the other lot was given corn plus casein equal to about one-tenth of the corn. The corn lot grew in 180 days from an average initial weight of 25.3 to an average final weight of 37.6 pounds, whereas the average change in the corn-casein lot was from 31 to 142 pounds. Here a comparatively small addition of casein changed the ration from one that permitted very little growth to one that induced growth which was nine times greater.

The nutritive value of the protein mixture of a food can be predicted only as the amino acid content is known. Corn is known to be deficient in two amino acids, tryptophan and lysine. Whole wheat, oats, rice, barley, rye, and millet have all been found to be deficient in lysine. It has been pointed out that if the lysine value of wheat were approximately doubled, a given amount of wheat protein would be twice as efficient in the building of tissue in the growing animal.

Legumes (peas and beans) are deficient in tryptophan and methionine, but they have only a small deficiency in lysine. Soybeans, on the other hand, have a good mixture of amino acids with the exception of the deficiency of methionine.

Even root products, such as potatoes, have been found to be important sources of protein in some areas. The white potato, for example, has a good assortment of amino acids except for a shortage of methionine.

Since a large proportion of the calories are furnished by the above foods in many parts of the world, the amino acids most likely to be deficient in human diets may be summed up as follows: lysine, methionine, threonine, and tryptophan. Flodin³ has suggested

³ Flodin, N. W. "Amino Acids and Proteins—Their Place in Human Nutrition Problems." *Journal of Agricultural and Food Chemistry*, Vol. 1, page 222 (1953).

the possibility of supplementing the diets in those parts of the world where low-quality proteins predominate with these four amino acids. Diets containing assortments of grains, legumes, and the various root vegetables will provide a better combination of amino acids because these foods when combined supplement one another and to some extent will provide the essential amino acids needed. However, the addition of protein from foods known to provide all of the essential amino acids such as milk, eggs, meat, fish, or poultry, will insure generous allowances of essential amino acids. It has been suggested that if half or more of the total protein in the diet is furnished by these good sources of essential amino acids, a satisfactory margin of safety will be attained for the human adult. For young children and adolescents probably two-thirds to three-fourths of the total protein should come from milk and foods containing good quality proteins in order to provide adequately for growth. During pregnancy and lactation a half to two-thirds of the protein should come from foods carrying good quality proteins with the greatest emphasis placed on milk.

Leverton, in her studies with young college women on two levels of protein, has demonstrated the importance of having high-quality protein in each meal if the nitrogen is to be well utilized. On the lower protein intake, animal protein in the form of milk showed a distinct advantage in reducing the loss of nitrogen in the urine.

Cannon, working with protein-depleted rats, showed clearly that unless all of the 10 essential amino acids were fed at approximately the same time the rats failed to make steady gains in weight. When the basal ration contained 5 amino acids in one portion and 5 in a second portion and the portions were fed alternately, poor weight recovery resulted. He concluded that for effective tissue synthesis all essential amino acids must be available simultaneously.

Effects of Prolonged Protein Malnutrition

A form of malnutrition known as protein malnutrition occurring in young children in large areas of the world has been recognized only within the past few years. In some parts of Africa it has been said that almost every child suffers from it and the mortality rate has been as high as 50 per cent among cases admitted to the hospitals. In other areas the mortality rate is between 30 and 40 per cent. It is more common in children under five years and is more likely to

Protein

occur during the weaning and post-weaning period. In central Africa the disease is well known as kwashiorkor, which means "red boy," so called because of red hair coloring which results. In other parts of the world the FAO reports that the same condition is recognized by as many as 50 other names including such terms as "infantile pellagra," "sugar baby," "fatty liver disease," and "nutritional edema syndrome." The condition has been found to be common in the Far East, India, the West Indies, Central America, and in many parts of South America.

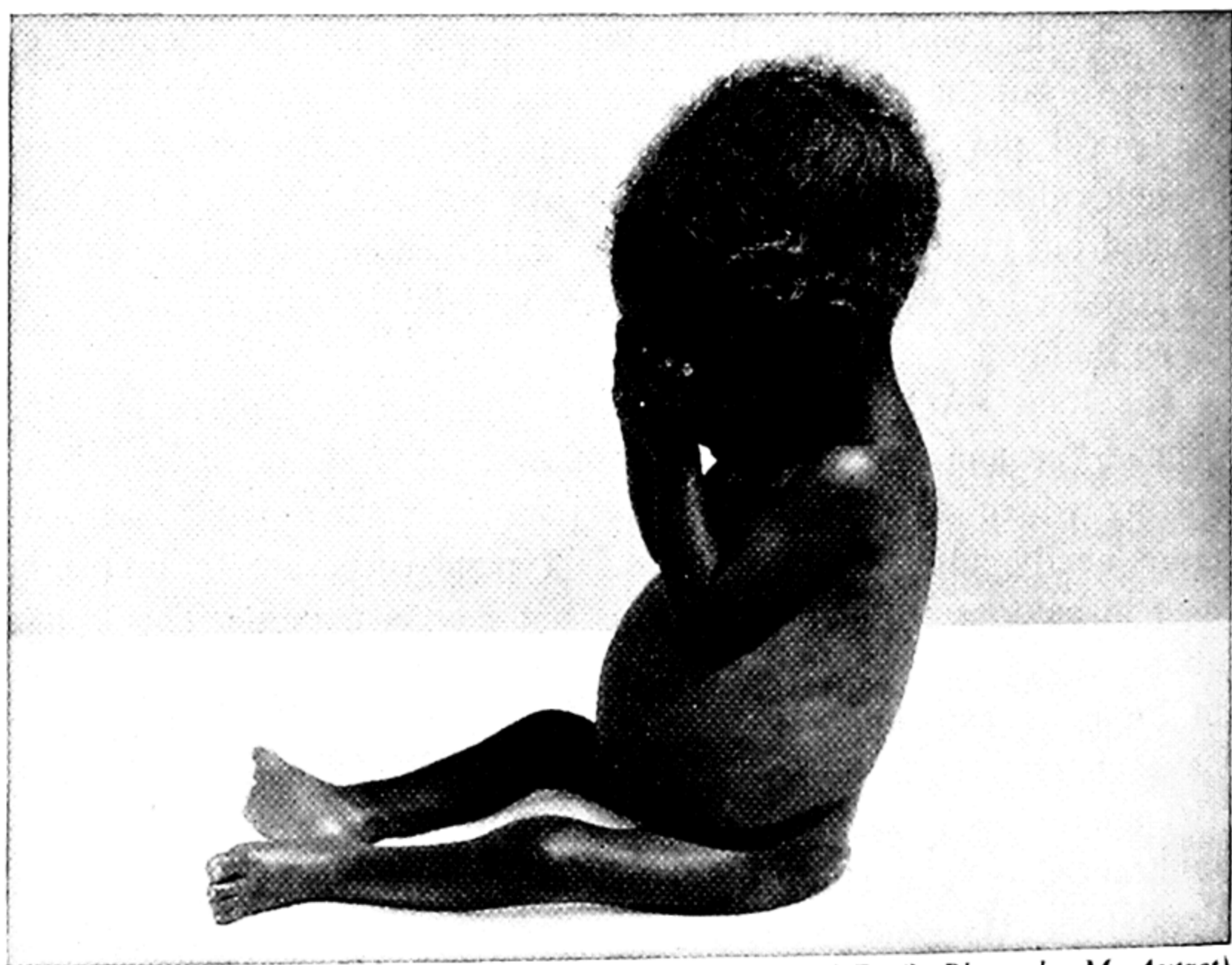
In classic kwashiorkor the calorie intakes may be adequate or nearly so but the protein is inadequate. However, in many parts of the world the children suffering from kwashiorkor do not have enough calories. If the calorie needs are not met, then, as has been pointed out in a previous discussion, some protein will be wasted in the production of energy, thus making less protein available for tissue building.

The Joint FAO and WHO Expert Nutrition Committee in 1952 defined "protein malnutrition" as follows: "A state of ill health occurring where diets are habitually poor in protein while they are more nearly adequate in calories." Typical diets are found to be high in calories from starchy foods but low in protein. This brings about an imbalance of amino acids and a deficiency of factors found in foods in association with animal proteins. Brock and Autret⁴ have characterized the syndrome as follows: (a) retarded growth, (b) alterations in skin and hair pigmentation, (c) edema, (d) fatty infiltration, cellular necrosis, or fibrosis of the liver, (e) nutritional dermatosis, (f) gastrointestinal disorders, (g) peevishness and mental apathy. See Fig. 40 for typical symptoms.

The most effective treatment is the introduction of skim milk powder. Where this has been successfully accomplished the mortality rate has fallen rapidly, in some areas almost to the vanishing point. In most cases dietary treatment will restore the health of children

⁴ Brock, J. F., and Autret, M. *Kwashiorkor in Africa*. World Health Organization, Geneva (1952); Brock, J. F. "Survey of the World Situation on Kwashiorkor." *Annals of the New York Academy of Sciences*, Vol. 57, page 696 (1954); Brock, J. F. "Chronic Protein Malnutrition." *Nutrition Reviews*, Vol. 13, page 1 (1955); Autret, M. and Behar, M. *Síndrome Policarencial Infantil (Kwashiorkor) and Its Prevention in Central America*. FAO Nutritional Studies No. 13, Food and Agriculture Organization of the United Nations, Rome (1954).

in a critical condition within a matter of weeks. In many countries children have no milk except mother's milk and as they change to the ordinary family diet, which is likely to be high in carbohydrates and poor in protein, the protein malnutrition develops. Since in many places enough milk for children cannot be produced at present and that which is available is too expensive, other protein-rich foods must be substituted. Soybean preparations have been used satisfactorily. Peanut flour, like soy flour, has also been found a good supple-



(Courtesy of FAO. Photo by M. Autret)

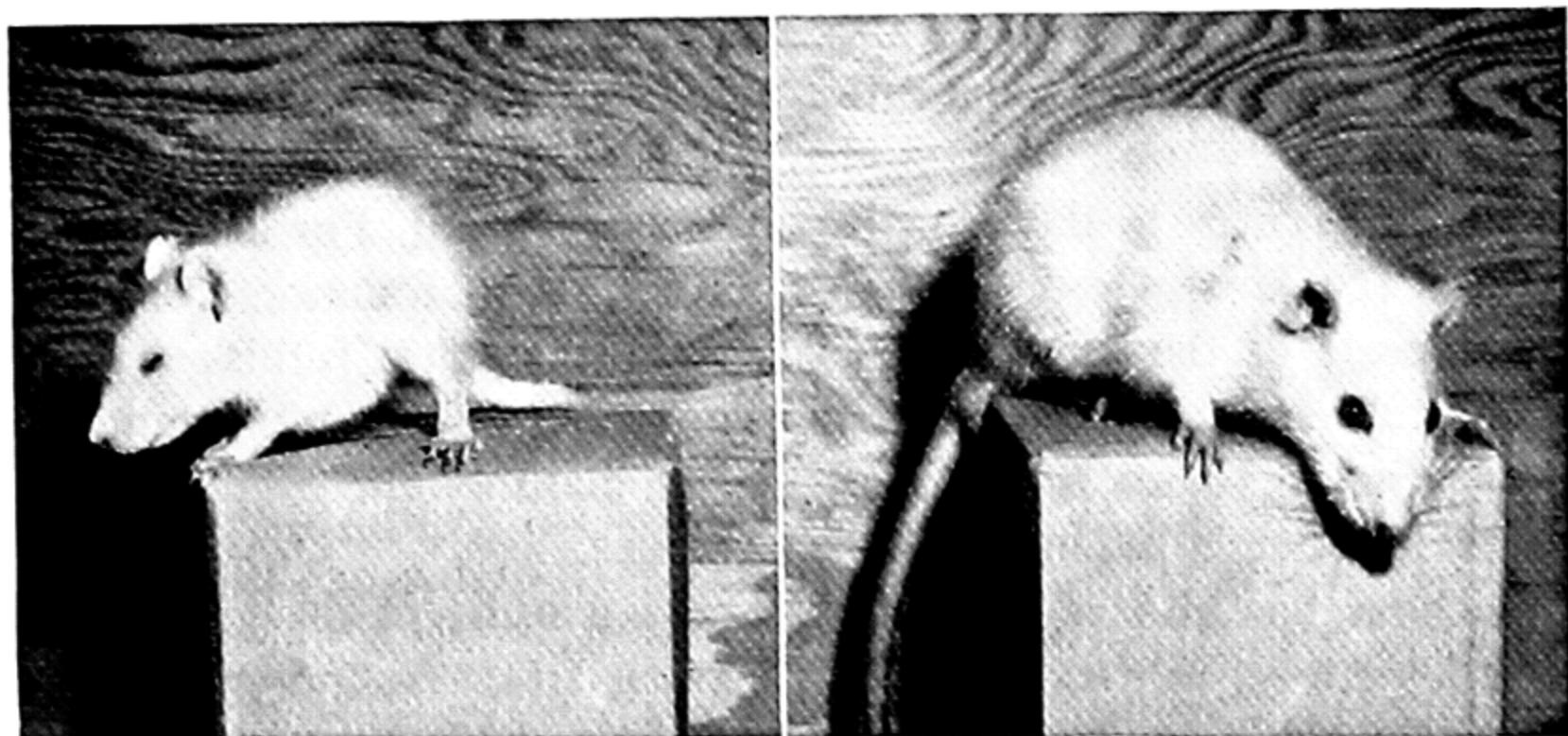
Fig. 40. An African Child Suffering from Kwashiorkor

Note the edema of the abdomen, dermatosis of the thigh, dyspigmentation and altered texture of the hair, and photophobia.

ment to the proteins of maize. Also, experimental work is under way on the use of fish flour as a source of good-quality protein. Brock and Autret report finding along the roadside in Northern Nigeria a small group of children between five and seven years of age who had the typical reddish hair. The area was known to have been affected seriously by famine. When the parents were asked if the color of the hair was natural they replied without hesitation that it would return to normal when their food improved.

Attention has recently been called to the high incidence of adult liver cirrhosis in those areas in the world where kwashiorkor is endemic. Although in the United States protein malnutrition is not a public health problem its frequency and significance elsewhere have stimulated research in liver metabolism.

See Fig. 41 for the effect of a kwashiorkor-producing diet in the rat.



(Nutrition Laboratory, Teachers College, Columbia University)

Fig. 41. The Effect of a Kwashiorkor-Producing Diet Compared with That of the Same Diet Plus Skim Milk Powder

The animals are the same age and had been on the diets 82 days. The only difference between the two diets was that one contained 86 grams of cassava (tapioca) while in the other 16 grams of the cassava were replaced by skim milk powder. The other ingredients of the diets were dried beans, banana flakes, meat residue, dried coconut, sugar, and palm oil. Note the typical symptoms of kwashiorkor—the dermatosis of the paws, nose, and ears, the edema of the abdomen, and the difference in texture of the fur of the animal on the left.

The Functions of Protein and Amino Acids

Promotion of growth is one of the most important functions of protein. Studies with experimental animals, already reported in this chapter, show that both the quality and the quantity of the protein must be considered if the best growth is to be attained.

When the diet furnishes optimum levels of protein such as are found in mother's milk, the growth of the young infant proceeds at such a rate that the newborn child doubles its weight in six months and triples it in a year, and we find that as much as one-third of the protein intake may be stored as body protein. Rubner reported a study of a premature infant who for 38 days retained for growth

one-half the protein eaten. To get the best storage, the protein of the food must be in itself efficient in promoting growth, and the supply of carbohydrate and fat must be liberal enough to protect the protein from being burned as body fuel. Milk is distinctly richer in tryptophan and lysine than the common run of foods, and the amino acids which it furnishes least liberally are those most easily derived from other foods.

Nicholls⁵ has pointed out that infants born of mothers with different racial backgrounds do not differ greatly in size, and growth proceeds at about the same rate for the first few months. But when the high-quality protein of mother's milk is supplemented by other foods, differences in the growth patterns are noted. For example, if manioc (cassava, a root vegetable), which is so commonly used in many parts of the world, especially in the tropics, furnishes most of the calories, the growth is poor. This lower growth rate continues if the diet continues to be poor, and at maturity the differences in weight and height attained may be striking.

Nicholls has also reported an interesting study of the growth attained by boys in Ceylon. Those coming from the poorer classes where the diets contained little high-quality protein grew at a slower rate than the boys from well-to-do families where the diets contained higher levels of good-quality protein. Similar findings have been reported in other situations which were formerly attributed to differences in heredity. It is now recognized that genetic differences are probably of less significance in the growth attained by racial groups than the quality of the diet.

The FAO World Food Survey of 1952 reported data on the calories per capita per day, the total protein, animal protein, and pulse (legume) protein in the average food supplies of 60 regions, subregions, and countries, and in the same year the Department of Social Affairs of the United Nations in a *Preliminary Report on the World Social Situation* gave life expectancy figures for some 44 countries. In the following tabulation will be found data from these two reports for 15 of these countries. Undoubtedly, factors such as sanitation and the adequacy of the diet from the standpoints of mineral elements and vitamins are also involved and should not be overlooked. It is of interest to note how life expectancy in most instances

⁵ Nicholls, L. *Tropical Nutrition and Dietetics*. Bailliere, Tindall, and Cox (1951).

Protein

increases as the amount of animal protein (from milk, eggs, fish, meat, poultry) per capita per day goes up.

<i>Country</i>	<i>Period</i>	<i>Calories per Capita per Day</i>	<i>Protein Grams per Capita per Day</i>			<i>Life Expectancy ^a</i>	
			<i>Total</i>	<i>Animal</i>	<i>Pulse</i>	<i>Period</i>	<i>Years ^b</i>
India	1949-50	1,700	44	6	10	1950	27
China	1949-50	2,030	63	6	16	*	*
Japan	1949-50	2,100	53	8	1	1949-50	57.9
Philippines	1949-50	1,960	44	10	2	*	*
Mexico	1946-49	2,050	55	16	5	1940	38.9
Venezuela	1946-49	2,160	60	23	10	1941-42	46.7
U.S.S.R.	1949-50	3,020	97	25	7	*	*
West Germany	1949-50	2,640	78	30	2	1946-47	60.6
Belgium- Luxembourg	1949-50	2,770	81	36	2	1946-49	64.7
France	1949-50	2,770	99	40	2	1946-49	64.7
United Kingdom	1949-50	3,100	92	49	2	1950	68.9
Denmark	1949-50	3,160	99	55	1	1946-50	69.0
Canada	1948-49	3,060	92	57	4	1947	67.1
U.S.A.	1948-49	3,130	90	60	4	1949	68.7 ^c
Australia	1948-49	3,160	95	65	2	1946-48	68.4

^a Data chiefly from *Preliminary Report on the World Social Situation*, United Nations, Department of Social Affairs, 1952. All other data in the table are from *Second World Food Survey*, Food and Agriculture Organization of the United Nations, 1952.

^b Average of males and females.

^c Average for white males and females. In 1955 this is reported by the Metropolitan Life Insurance Company to be 69.8 years for wage earners and their families.

* No data recent enough for fair comparison with data from the World Food Survey.

Other effects of protein deficiency may be manifested, such as, a deficiency of muscle development which, according to Jeans, may account for the poor posture of many four-year-old children or low plasma protein with a decline in serum albumin and globulin which leads to hypoproteinemia. The low hemoglobin levels which accompany this condition will respond to an increase of the protein in the diet. Resistance to infections is lowered as well as the level of phagocytes (white cells) and antibodies in the blood. Cannon has demonstrated that adult animals maintained on a low-protein diet over a prolonged period lose their ability to form antibodies and resist infection. It is suggested that only under an extreme protein deficiency, which is rarely experienced in human nutrition, will the level of protein intake become the governing factor in antibody re-

sponse. Many reports show, however, a relationship between prolonged low protein intakes and tuberculosis, rheumatic fever, and respiratory and intestinal infections. The desirability of high-quality protein for convalescence from surgery, in the healing of wounds, and for superior rate of recovery from disease has been stressed by a number of investigators.

The possible relationship between glutamic acid (one of the non-essential amino acids) and mental functions has been of interest over a period of years. The use of glutamic acid in apparently increasing the intelligence of a group of epileptic children has brought about further study of groups of children with low mental ability. No consistent gains have been established, and the effectiveness of glutamic acid for this purpose is doubtful.

The functions of a number of amino acids are known to be inter-related with those of a number of vitamins, for example, tryptophan serves as a precursor of niacin in the prevention of pellagra. The relation of methionine to vitamin B₁₂ and choline, and of tyrosine to ascorbic acid, has been recognized, but it seems desirable to discuss these interrelationships in the respective chapters on vitamins.

Protein Requirement

When foods are eaten the complex protein molecules are broken down into amino acids in the process of digestion. From what we have learned of the great diversity in amino acid content of different proteins, we shall not be surprised to find that when the final assortment from a meal has entered the blood stream and the cells of the tissues have begun to take up the particular kinds of amino acids which are required for their individual needs, there may be an over-supply of some and a scarcity of others. One cannot build a protein containing 18 kinds of amino acids, for example, from an assortment in which 2 are completely lacking, any more than one can make a dress with cloth but no thread. Nor can one build a protein containing many lysine radicals from an assortment which has very few, any more than one can make a garment from 1 yard of cloth when the pattern calls for 5, even though one had 100 spools of thread.

Any amino acids left over in the blood stream, after the different cells have taken out those which meet their needs, become available for use as body fuel, just as the odds and ends of timber from the

building of a house may be later turned to account in the fireplace. When amino acids are burned for fuel they are broken down into simpler compounds, the nitrogen being converted into urea and a small amount of ammonia, which are withdrawn from the blood by the kidneys and excreted in the urine, and the remainder reduced to compounds containing only carbon, hydrogen, and oxygen, which burn like sugar and fat. Fifty-eight per cent of the weight of the protein may thus turn to sugar (glucose) and be burned along with other carbohydrates and fat for fuel. Any surplus protein is burned up. We have but little power to store protein against future need as we can store carbohydrate and fat. The more we eat the more we burn, and urea excretion becomes a rough measure of the amount of protein used as fuel.

The functions of protein as body-building material and as a source of energy thus fit into one another, and it is impossible to tell in advance exactly how much of the protein eaten will serve each purpose. The most practical ways to study the quantity of protein required are by the feeding experiments with animals, noting just how much must be fed to sustain life without growth and how much must be added to insure normal growth, or by chemical studies of the nitrogen balance (the amount of nitrogen in the urine and the feces compared with the amount in the diet).

In studying protein requirement, it is simpler to consider first the nitrogen requirement of the healthy adult, uncomplicated by the phenomena of growth. Critical examination by Sherman in 1920 of over 100 nitrogen balance experiments in 25 independent investigations, including work in several countries and with both sexes, gave an average of 44 grams of protein per 70 kilograms of body weight per day as the minimum requirement. Stare and his co-workers in 1946 reported on experiments with 26 healthy adults on a basal low-protein diet and found the protein requirement to be between 30 and 40 grams for a 70-kilogram adult. These studies and others indicate that the average minimum requirement is close to 0.5 gram of protein per kilogram of body weight.

Since protein in excess of requirement is readily burned as fuel, there is no particular reason for trying to keep the amount in the daily diet down to the minimum. It is actually difficult to do so in the United States because of the richness in protein of many of the foods commonly used. Moreover, considering the somewhat uncer-

tain amino acid assortment from a diversified diet, and the likelihood of fluctuations in completeness of digestion, it would not be wise to adopt a minimum standard for practical living.

The real question, then, is not how little protein do we need, but how much is it desirable to indulge in? The Eskimo eats two to three times as much protein as most dwellers in the temperate zone. In the tropics, however, the consumption of protein is often not more than half that of the temperate zone. Professor Krogh, of the University of Copenhagen, estimated that the calories in the three types of diet were distributed somewhat as in the table below. If men can

DISTRIBUTION OF CALORIES IN DIETS OF DIFFERENT RACES

	<i>Weight, Kg.</i>	<i>Protein, Gm.</i>	<i>Total Calories</i>	<i>Distribution of Calories, Per Cent</i>		
				<i>Protein</i>	<i>Fat</i>	<i>Carbo- hydrate</i>
Eskimo	65	282	2,604	44	48	8
Bengali	50	52	2,390	9	10	81
European	70	118	3,055	16	17	67

adapt themselves so readily, does it make any difference how far above requirement we set our practice?

In answering this question, we must remember that the Eskimo eats meat because he has to. An Eskimo family of four easily consumes 4,000 pounds of meat (mink, muskrat, caribou, seal) a year, but bread, fresh vegetables, fresh fruit, salt, and sweets are lacking. The children suck frozen eggs as the children of America suck lollipops. There is very little carbohydrate food to be had—a reindeer stomach now and then as a delicacy, its contents partly digested moss; lichens; or perhaps the skin of a young whale, rich in glycogen—so the Eskimo must manufacture from his protein the glucose which enables him to burn fat satisfactorily. Furthermore, in the Arctic winter, when “in semi-darkness the Eskimo family sits fully dressed upon the bed platform listening to the roar and whizz of wind and drifting snow past the translucent windows of seal intestines,”⁶ the extra heat produced by the stimulating effect on the energy output of a high protein diet helps to create comfort in that inhospitable climate. In warmer regions there does not seem to be

⁶ Macmillan, D. B. “Food Supply of the Smith Sound Eskimos.” *American Museum Journal*, March issue, page 172 (1918).

Protein

any good reason for such generous use of protein, when carbohydrate food is everywhere obtainable and much the cheaper and when extra heat production from food frequently means so much more heat to get rid of lest it cause real discomfort. To what extent climate influences the ease with which the kidneys eliminate nitrogenous waste is not known, but there does not seem to be any good reason for putting an unnecessary load upon them, any more than there is for straining one's back to lift a trunk just to see how far one can tax his muscles. We have no easily applied measure of kidney endurance and, inasmuch as their fitness is indispensable to well-being, it would seem only sensible to undertax rather than overtax them.

Protein does not exert any marked stimulating effect on heat production when it constitutes a relatively small proportion of the total calories, i.e., not over 10 to 15 per cent. Assuming the average daily energy expenditure of a sedentary man (wt., 70 kg.) to be 2,500 calories, 10 per cent or 250 calories in the form of protein would be equivalent to 62.5 grams of protein, equal to 0.9 gram of protein per kilogram, while actual requirement is, as we have seen, about 0.5 gram per kilogram. Hence, an allowance of 10 per cent of the total calories in this case means 80 per cent more than required, which should allow for varying efficiency of proteins of different amino acid make-up, provided some proteins of high efficiency, such as those of milk, eggs, or meat, are included in a mixed diet. Sherman (1952), reviewing the experimental work on the effects of different levels of protein intake upon normal nutrition throughout the life cycle, concluded that the results confirmed and strengthened the generally accepted dietetic custom of allowing from 10 to 15 per cent of the total food calories for protein under ordinary conditions. There seems to be no reason why conditions for growth need be less favorable when the protein calories constitute as much as 15 per cent of the total calories. A liberal supply may be turned to good account in periods of unusually rapid growth.

Recommended Allowances for Protein

The protein allowances recommended by the Food and Nutrition Board of the National Research Council will be found in the Appendix. It will be noted that 1 gram of protein per kilogram of body weight per day has been suggested for normal adults regardless of muscular activity. This increase of 0.5 gram above the average requirement for protein provides for individual variation in the protein

requirements of normal people and also for differences in the quality of the proteins in the daily food supply.

The recommended allowance of 1 gram of protein per kilogram of body weight is twice the minimum requirement. If we take, for example, a sedentary man weighing 65 kilograms and needing 2,500 calories per day (see Tables I(a) and III(a) in Appendix), he will need 65 grams of protein or 260 calories which is about 10 per cent of the total calories. If this man were moderately active and needed 3,000 calories the calories from protein would be less than 10 per cent. Practically, when one follows the general rules for the selection of an adequate diet (see Chapter 25) the chances are that the per cent of the calories from protein will be nearer the 15 per cent level. Since the foods furnishing protein are readily available in the markets in the United States, it is unlikely that the protein intake would fall below that recommended.

The protein allowance during pregnancy is increased from 55 grams of protein per day, or about 10 per cent of the calories for the nonpregnant woman, to 80 grams per day, or about 12 per cent of the calories needed for pregnancy, the increase starting in the latter half of pregnancy when the growth of the fetus is most rapid. During lactation the daily allowance is increased still further to 100 grams of protein per day. Since the total calories are also increased the per cent of the calories coming from protein is still about 12 per cent.

In human milk about 9 per cent of the calories are in the form of protein and this provides from 2 to 2½ grams of protein per kilogram of body weight per day for the young infant.

The recommendations for children will vary according to age, and for convenience they are tabulated below:

			<i>Protein</i>		
	<i>Age</i>	<i>Calories</i>	<i>Gm. per Day</i>	<i>Per Cent of Total Cals.</i>	<i>Gm. per Kg. of Wt. per Day</i>
Children	1-3	1,200	40	13	3.3
	4-6	1,600	50	13	2.8
	7-9	2,000	60	12	2.2
Boys	10-12	2,500	70	11	2.0
	13-15	3,200	85	11	1.7
	16-20	3,800	100	11	1.6
Girls	10-12	2,300	70	12	1.9
	13-15	2,500	80	13	1.6
	16-20	2,400	75	13	1.4

It will be noted that the protein recommended for children furnishes from 11 to 13 per cent of the total calories. One quart of milk, which furnishes 34 grams of protein of excellent quality as well as other important dietary factors, is a desirable safeguard in the daily diet of the growing child.

In Figure 42 will be found a selection of common foods furnishing equal amounts of protein (6.1 grams).

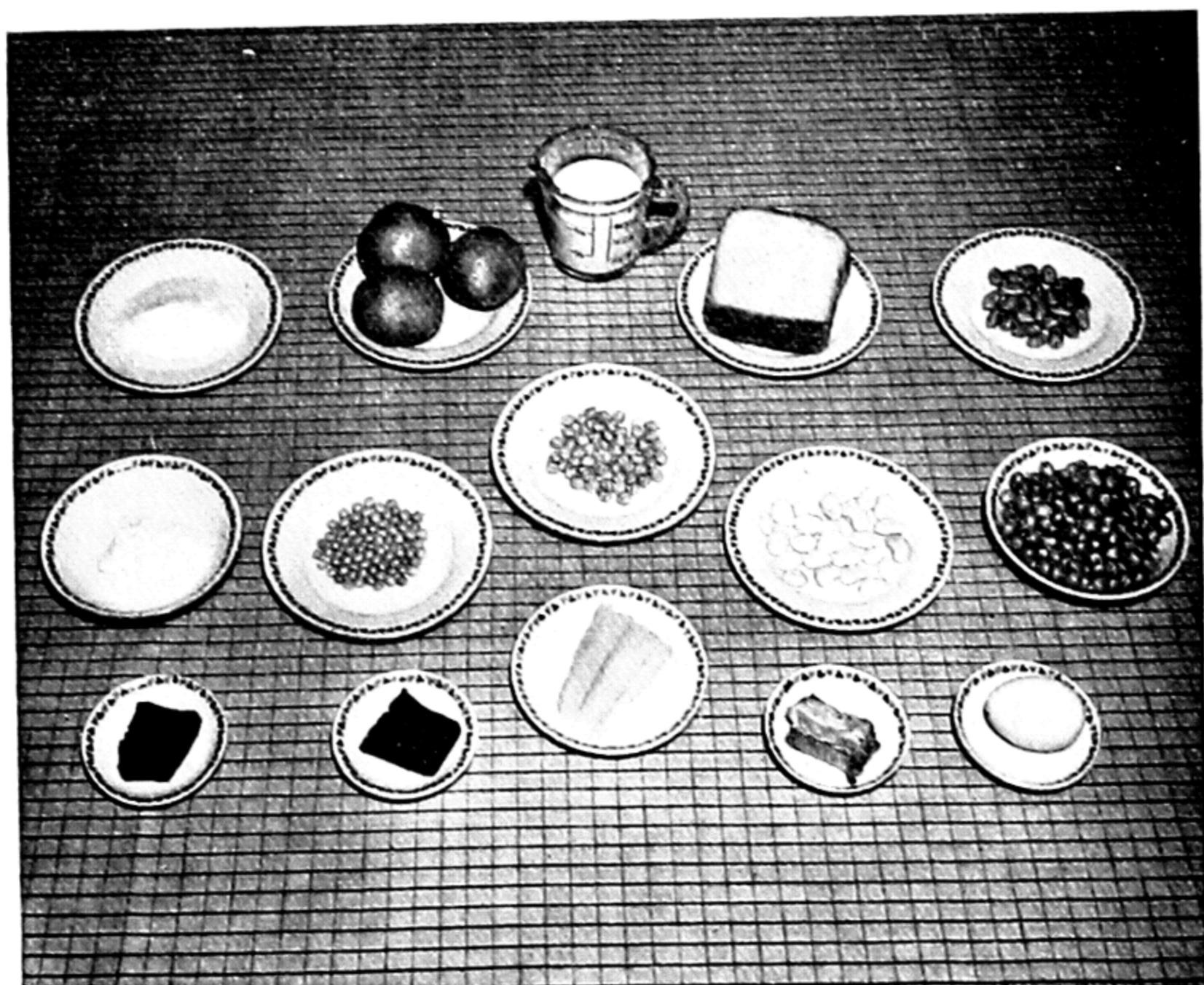


Fig. 42. Food Portions Yielding 6.1 Grams (Three Shares) of Protein

	<i>Grams</i>		<i>Grams</i>
Milk, dried skim	17	Lima beans, dried	29
Potatoes	300	Peas, fresh	91
Milk, whole	176	Beef, lean	29
Bread, white, enriched	71	Liver, beef	31
Peanuts	23	Fish, cod, raw	37
Cheese, cottage	31	Chicken, canned, boned	20
Soybeans, dried	17	Egg, cooked	53
Garbanzos (chickpeas)	29		

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Mineral Elements

The mineral elements which are essential components of the human body will be realized better, perhaps, if we make a list showing the approximate amount of each present in the organism:

MINERAL ELEMENTS IN THE HUMAN BODY

<i>Element</i>	<i>Amount in a 70 Kg. Man, Grams</i>
Calcium	1,295
Phosphorus	700
Potassium	245
Sulfur	175
Sodium	105
Chlorine	105
Magnesium	35
Iron	2.8
Manganese	0.21
Copper	0.105
Iodine	0.028
Cobalt	} Very minute quantities
Fluorine	
Molybdenum	
Zinc	
Others reported but functions doubtful	

Traces of other elements, e.g., boron and silicon, may not be essential for man although they are probably essential for plants. In addition, other elements have been reported including aluminum, arsenic, bromine, chromium, lead, nickel, selenium, strontium, vanadium, and others. Some of these occur naturally in foods; others may have gained access through contamination, but whether they are essential to body structure has not yet been established. The term

"trace element" is used in referring to mineral elements which in extremely small amounts play some role in the nutrition of plants and animals.

The development of new instruments for analysis, such as the electronic recording spectrograph, has made it possible to extend our information on the amounts of trace elements in plants used for food. Recent studies of Bear in the Department of Soils of the New Jersey Agricultural Experiment Station show that specific deficiency symptoms occur in plants due to the absence or inadequate amounts of various trace elements. For example, with a molybdenum deficiency, the older leaves of cauliflower become long and slender, and with a boron deficiency, black areas have been found in the stem centers of cabbage and cracked areas have been found in celery stems. These studies demonstrate the critical role which trace elements play in plant production and point to the possibility of a more far-reaching effect with respect to the health and well-being of animals and man than has heretofore been appreciated.

However, it must be kept in mind that it is the healthy well-formed plants that have a market value and with the wide occurrence of these trace elements in the food included in an all-round good diet, it is not likely that a deficiency will occur in human nutrition. In our enthusiasm about the importance of trace elements, we have to be careful not to become victims of the pseudo scientist. L. A. Maynard,¹ former Director of the School of Nutrition at Cornell University, sums up our present knowledge as follows: ". . . with the exception of the long-recognized case of iodine, none of the reports which have suggested correlations between soil deficiencies and human diseases have been based on studies or observations which were sufficiently critical to establish any direct relationships. . . ."

We depend upon food for a supply of all needed mineral elements, just as we depend upon it for the various amino acids which are built into the body proteins. Pure carbohydrates and fats furnish none. We depend upon protein for our sulfur, found chiefly as an integral part of the amino acids cystine and methionine. Just as proteins vary in their proportion of cystine they vary also in their yield of sulfur, some, such as lactalbumin, being very rich in it and others,

¹ Maynard, L. A. "Soils and Health." *Journal of the American Medical Association*, Vol. 143, page 807 (1950). Review. "Trace Elements in Plants and Soils." *Nutrition Reviews*, Vol. 12, page 276 (1954).

as gelatin, lacking it entirely. Food iron is frequently combined with protein, not only in the hematogen of egg yolk and the hemoglobin of blood but also in food materials which we do not usually consider rich in protein, such as the green parts of plants and outer coats of grains. While certain proteins are rich in phosphorus, e.g., the vitellin of egg yolk and the casein of milk; and certain ones unite readily with calcium, the most important being casein, we are not dependent upon proteins for either calcium or phosphorus.

With the exception of sodium and chlorine, which we get chiefly combined as common table salt (sodium chloride), the mineral elements of the diet are drawn from a great variety of sources and only tables showing the chemical composition of food materials will give satisfactory information in regard to their distribution.²

Section 1. MINERAL ELEMENTS AS BODY BUILDING MATERIAL

Quantitatively the mineral elements most prominent in the body are calcium and phosphorus. They chiefly are responsible for the rigidity of the bones and teeth. Altogether, approximately 99 per cent of the total calcium and 90 per cent of the total phosphorus of the body are in the skeletal tissues, and serve to maintain the framework whose value we most appreciate when we see the effect on health and beauty of poor teeth or of a disease like rickets, in which the mineral deficiency of the bones may result in a hollow chest and poorly developed lungs, to say nothing of the unattractiveness of bowlegs, knock-knees, or flat feet.

The structure and the functions of the human body cannot be well understood without appreciation of the fact that the cell, a microscopic mass of protoplasm, is a unit endowed with all the attributes of life.³ The egg cell divides into two daughter cells, which in turn divide each into two others, until there are finally billions and billions of cells, differentiated in the process of development for various functions: some for building skeleton, others for nerves,

² See Appendix, Tables II and IV, for calcium and iron figures. See also Taylor and MacLeod. *Rose's Laboratory Handbook for Dietetics*, 5th edition, page 260. The Macmillan Co. (1949).

³ For an adequate description of the cell and its relation to body structure as a whole recourse must be had to standard works on biology.

others for the digestive system, etc. In a cubic inch of normal human blood there are said to be as many as 80 billion cells, red and white, all equipped for special chemical work.

The life of the cell is governed by a minute but highly organized mass of protoplasm called the nucleus. It consists of a netlike framework whose meshes are filled with a special kind of protein called nucleoprotein and whose threads entangle granules of chromatin, consisting of highly complex proteins containing iron. Upon the integrity and the efficiency of the chromatin substance of the nucleus depend the nutrition, growth, and reproduction of the cell and hence the very life of the organism as a whole. A diminution or withdrawal of the supply of iron, therefore, interferes with fundamental nutritional processes.

The proteins of the cell nucleus, nucleoproteins, are distinguished by the fact that they contain phosphorus as an integral part of their structure; hence phosphorus, like iron, is intimately associated with the fundamental processes of nutrition, sharing in the control of cell activities.

The body of the cell, the cytoplasm as it is called, contains, in addition to protein, mineral salts, water, and another substance called lecithin, allied to the fats but having phosphorus as an indispensable element in its composition. Lecithin helps the cell to connect with its environment, to absorb nourishment, to eliminate waste, or to discharge some product of its own chemical activity for the benefit of other parts of the organism.

Among cells differentiated for special function are the red corpuscles of the blood, which are the carriers of oxygen to all the tissues and the removers of carbon dioxide arising from the combustion of body fuel. Their power to transport these gases depends upon an iron-bearing protein, hemoglobin, and any serious diminution in its amount is accompanied by increased respiration and accelerated heart action in an effort to compensate for the lessened carrying capacity of the blood.

Phosphorus and iron are as essential to every living cell as nitrogen. On this point we may quote two authorities on the metabolism of these elements. Forbes, formerly Director of the Animal Nutrition Laboratory at the Pennsylvania State College, said in regard to phosphorus: "Among the several inorganic elements involved in animal life phosphorus is of especial interest. No other one enters

into such a diversity of compounds and plays an important part in so many functions. Structurally, it is important as a constituent of every cell nucleus and so of all cellular structure; it is also prominent in the skeleton, in milk, in sexual elements, glandular tissue and the nervous system.”⁴ And Sherman, whose own researches on iron contributed much to our early knowledge of iron, said in regard to this element: “Iron stands in the closest possible relation to the fundamental processes of nutrition, being an essential constituent both of the oxygen-carrying constituents of the blood and of the substances which appear to control the most important activities within the cell.”⁵

The other mineral elements are found variously distributed in the body, chlorine occurring chiefly in the gastric juice; sodium, in the blood and other fluids, combined with chlorine as sodium chloride (common salt); potassium, most abundantly in the protoplasm of muscles and various organs; magnesium, chiefly in the bones but also in muscles and a little in blood; iodine, in the thyroid gland and its product, thyroxine; zinc, an integral component of enzymes in the blood cells and the pancreas; and molybdenum, in an enzyme (xanthine oxidase) found in the liver, apparently one of the major elements in controlling cellular respiration. Copper is very closely associated with iron in animal tissues. It is found in high percentage in the liver, especially of the newborn. Although it does not enter into the structure of hemoglobin, it is essential to its formation. While these elements contribute to the composition of the body, they function more prominently in the regulation of body processes.

Section 2. MINERAL ELEMENTS AS REGULATORS OF BODY PROCESSES

We have seen in Section 1 that chemical elements which may enter into the structure of the body in very minute quantities are highly important for the maintenance and growth of the cells. In the regulation of body processes, the amount of an element present

⁴ Forbes, E. B., and Keith, H. M. *A Review of the Literature of Phosphorus Compounds in Animal Metabolism*, page 11. Ohio Agricultural Experiment Station, Technical Bulletin No. 5 (1915).

⁵ Sherman, H. C. *Iron in Food and Nutrition*, page 7. U. S. Department of Agriculture, Office of Experiment Stations, Bulletin No. 185 (1907).

in the organism gives no clue as to its significance in the coordination of cell functions. Each element has its own special part to play; two which may be closely related chemically cannot exchange places and may in some of their functions be actually antagonistic to each other. Inasmuch as the role of the mineral salts in vital processes is a matter of their physiochemical relationships, any detailed discussion of their functions leads far into the fields of chemistry and physics, and is beyond the scope of this book. No attempt will be made to do more than discuss briefly some of the more obvious ways in which the mineral elements aid in the regulation of body processes.

In the first place, these elements influence the contractility of muscles. If a muscle is removed from the body and put into a solution containing a suitable mixture of pure salts (particularly calcium, sodium, and potassium chlorides) it will, when stimulated, contract as it would in the body. But if it is put into distilled water (which contains no such salts) it will not respond when stimulated. If the muscle is put into a solution containing sodium and potassium, but not calcium, it will fail to respond; but when calcium is added in suitable amount to the solution, it will respond as at first. Thus the dependence of the muscle upon calcium may be demonstrated in the laboratory. It may also be demonstrated by the use of a frog's heart, which can be made to beat or stop as calcium is present or absent from a solution in which the organ has been suspended. So we say the muscles of the heart depend for their rhythmic beat upon the nature of the salts in the fluids which bathe them.

In the second place, minerals determine the irritability of nerves. Just as a muscle will not contract normally if suspended in distilled water, so a nerve similarly placed will fail to respond to any stimulus, but when bathed with a suitable salt solution will behave in the normal manner. All the organs regulated by the central nervous system depend for the integrity of their functions not only upon the presence of calcium, potassium, and sodium in the fluids within the nerve tissues, but upon their presence there in just the right proportions.

In the third place, mineral elements control the movement of liquids in the body. Digested food materials must pass freely from the intestine into the blood stream without any blood passing back into the intestines. Also, liquids must pass from the blood into the various

organs and tissues, and such a fluid as the gastric juice must be derived from the blood and poured into the stomach. Furthermore, the waste matter of the cells taken away by the blood must be withdrawn from it by the kidneys and discharged in the watery solution which we call urine. It is due to interactions between mineral elements that the cells can bring these things to pass.

Another function of mineral elements is to assist in the coagulation of the blood. Any wound, however slight, would threaten death by bleeding had we not this interesting protective mechanism, whose value we appreciate only when we learn of certain persons known as "bleeders," whose blood does not clot readily, even after a pin prick. Calcium is one of the important factors in the coagulation process.

Mineral elements are essential also to the digestive processes. For example, in the stomach, the gastric juice owes its characteristic acidity to hydrochloric acid, upon which the activity of pepsin in digestion depends. In the small intestine, other mineral salts make the secretions alkaline, favoring the digestive processes there, especially the digestion of fat.

Another important function is to keep the blood neutral—neither acid nor alkaline. Here phosphorus (as phosphoric acid) and sodium (as bicarbonate) act as buffers, which means that, when they are present in a solution, considerable amounts of acid or alkali may be added without showing any effect, for they change so as to dispose of the acid or alkali as such and keep the solution neutral. The situation is somewhat like that of two children of unequal weight at each end of a teeter; they solve the difficulty of not being able to move up and down on account of their weight inequality by placing a third child in the middle to serve as a buffer, i.e., to move first toward one child and then toward the other, thus adding his weight where it is needed at the moment.

Mineral elements take part in the transport of oxygen from the lungs to the tissues and of carbon dioxide from the tissues to the lungs which alone makes possible the continued combustion of fuel foods. As previously pointed out, the power of the iron-bearing hemoglobin of the blood to combine under certain conditions with oxygen and under other conditions with carbon dioxide is fundamental to the process of respiration.

As the mineral elements enter into the composition of every living

cell, they determine the vital processes of oxidation, secretion, development, and reproduction. Phosphorus and iron, indispensable to every active cell, as shown in Section 1, are outstanding examples of such controlling elements.

Mineral elements are essential to the structure of certain complex chemical compounds which profoundly influence the course of metabolism. One conspicuous example is iodine, the element found in the thyroid gland and its product thyroxine, which has been referred to in Chapter 2 as powerfully influencing the energy metabolism. But this is not all. Without iodine for the proper functioning of the thyroid, normal growth in the young and the maintenance of health in the adult are impossible. The influence on development is strikingly shown in the case of tadpoles; ordinarily they require three weeks to change into frogs; given thyroid, the metamorphosis begins in a few days and is completed so rapidly that there is no time for growth in substance along with the loss of tail and formation of legs, so that the result is pygmy frogs. In the human adult loss of thyroid function results in changes in skin, hair, facial contours, and other signs that a controlling mechanism is out of order.

Section 3. SULFUR

Sulfur is a component of body protein occurring chiefly in the amino acids cystine and methionine. Sulfur in the form of cystine is also a component of the hormone insulin, essential to normal metabolism of glucose, and of another chemical regulator of metabolism, glutathione. This latter substance, found and named by Professor F. Gowland Hopkins of Cambridge University in 1921, is present in many body tissues, and is an important factor in the control of oxidative processes in the body. Sulfur is an essential component of the vitamin, thiamine, the functions of which will be discussed in Chapter 13. As a constituent part of thiamine and of the respiratory enzyme, cocarboxylase, sulfur also plays a role in the metabolism of carbohydrates.

Sulfur in food is found almost exclusively in the form of protein. Individual proteins differ considerably in their yield of sulfur, but the foods which ordinarily contribute most of the protein of the diet average about one gram of sulfur for each 100 grams of protein, or each 16 grams of nitrogen.

As the metabolism of sulfur usually runs somewhat parallel to that of nitrogen in the ratio of about 1 gram of sulfur to 16 of nitrogen (corresponding to 100 grams of protein), we may assume for practical purposes that the sulfur requirement will be met when the protein intake is sufficient to meet the nitrogen requirement.

Section 4. SODIUM, POTASSIUM, AND CHLORINE

Sodium chloride (common table salt) is the only salt which we appear to crave in greater amount than is found naturally in food. The earliest recorded history shows the use of salt by civilized people and suggests that the practice may possibly have developed "at the time man made the transition from a nomadic hunter-fisher, on a roasted meat and milk diet, to an agriculturist on a cereal grain and vegetable diet."⁶ Herbivorous animals have long been known to travel great distances, if necessary, to salt licks while on the other hand, carnivorous animals show little interest in supplementary salt.

The manufacture of salt appears to have originated many centuries ago. Records show that in 2700 B.C. the Chinese obtained salt by solar evaporation of saline waters or by rock salt mining. The Phoenicians apparently were the first to engage in sea salt manufacture in the Mediterranean area. In Greece, slaves were bought and sold with salt and the good slave was said to be "worth his weight in salt." Through the years, men have been driven to fight, bargain, and travel from place to place to satisfy this great desire for salt. The American colonists also craved salt and during the early years it was necessary to import it, but soon it was found that salt could be obtained by boiling sea water and this was carried out along the shores of Massachusetts, Long Island, New Jersey, and elsewhere. Later the salt springs of Lake Onondaga in New York and the brine wells along the Kanawha River in southern Virginia were developed.⁷

The amount of sodium chloride taken in the form of common salt is far in excess of human requirements for sodium and chlorine. Furthermore, these elements are so widely distributed in food ma-

⁶ Meneely, Tucker, Darby, and Auerbach. "Chronic Sodium Chloride Toxicity: Hypertension, Renal and Vascular Lesions." *Annals of Internal Medicine*, Vol. 39, page 991 (1953).

⁷ Smith, J. R. "Salt." *Nutrition Reviews*, Vol. 11, page 33 (1953).

terials that there is little likelihood of shortage of either unless some specially restricted diet is employed over a long period of time or one is working under conditions of excessive heat. The main question is whether or not sodium chloride will be used to excess.

It is reported that the normal adult in the United States has an average daily intake of 7 to 15 grams of salt (approximately $\frac{1}{3}$ to 1 tablespoon) including the sodium and chlorides contained in foods together with those added as salt. In 1948, Osmond and Clements, in a study of 175 households in Australia, reported that the mean daily consumption of table salt per adult male was 5.5 grams. The sodium intake in the United States is about 3 to 6 grams per day in contrast to that of the Japanese who often consume 10 to 15 grams daily, part of which comes from soya sauce.

Large amounts of salt tend to stimulate the digestive tract and may thus interfere with the absorption of the food. Hence, it is not advisable to use foods preserved in salt for little children and invalids. A good rule is probably to add always a little less salt than you would like.

The Food and Nutrition Board of the National Research Council suggests that when performing unusually heavy work in a hot climate 10 to 15 grams of salt daily, or even more, may be required with meals and in drinking water. However, they state that after acclimatization to heat the amount can be reduced to near normal.

The beneficial effect of diets low in sodium in diseases affecting the circulation, such as, hypertension (elevation of blood pressure), congestive heart failure, and cirrhosis of the liver, has renewed interest in the functions of sodium chloride in physiologic processes. Sodium salts are found in greater amounts in the blood and other extracellular fluids than in the tissues. Potassium salts, on the other hand, occur in greater concentration within the cells of the soft tissues, the muscles, other organs, and in the blood corpuscles. Together, these salts participate in maintaining water balance and normal osmotic pressure. Fluctuations in water balance may have dire effects on the viability of the cells. Every cell in the body requires sodium and potassium and a proper balance between sodium, potassium, and calcium is essential for normal heart action. The importance of both sodium and potassium in conduction of nerve impulses and muscle contractibility (especially in the heart muscle) have already been pointed out. Sodium, potassium, and chlorine are

Mineral Elements

all important in the maintenance of water balance. Normally, mechanisms operate to conserve either water or sodium depending on the excess or deficiency of the materials ingested. The concentration in the body under normal conditions remains almost constant within a wide range of intake of either sodium or water.

The American Heart Association in 1952 suggested that foods to be called "Low Sodium Foods" should contain no more than the following milligrams of sodium per 100 grams:

Fruits	less than 15 mg.
Fruit juices	less than 15 mg.
Vegetables	less than 20 mg.
Meats, fish, fowl	less than 100 mg.
Fats	less than 5 mg.
Fluid or reconstituted milk from modified dry milk substitute (low sodium milk)	less than 15 mg.
Cereals	less than 5 mg.
Bread—low sodium	less than 10 mg.

Common portions of foods⁸ meeting these requirements can be selected from those listed below:

FRUITS AND FRUIT JUICES

Apples	Cherries	Oranges	Prunes
Apricots	Figs	Peaches	Raspberries
Blackberries	Grapefruit	Pears	Strawberries
Blueberries	Grapes	Pineapple	Tangerines
Cantaloupe	Lemons	Plums	Watermelon

VEGETABLES

Asparagus	Brussels sprouts	Mushrooms	Potato
Beans, snap or string	Cabbage	Okra	Pumpkin
Beans, lima	Corn	Onions	Squash
Beans, navy	Egg plant	Parsnips	Sweet potato
Broccoli	Escarole	Peas	Tomatoes
	Lettuce	Pepper, green	Turnips and greens

MEAT, FISH, FOWL, AND EGG YOLK

Beef	Duck	Heart	Salmon, fresh
Chicken	Egg yolk	Lamb	Sweetbreads
Cod, fresh	Halibut, fresh	Liver	Turkey ^a
		Pork	Veal

^a Average of light and dark meat.

⁸ For sodium values of foods, see Taylor and MacLeod. *Rose's Laboratory Handbook for Dietetics*, 5th edition. The Macmillan Co. (1949). Clifford, P. A. "Sodium Content of Foods." *Journal of the American Dietetic Association*, Vol. 31, page 21 (1955).

FATS

Butter (sweet) and other unsalted fats, such as salad oils.

BREADS AND CEREALS

Bread, unsalted	Maltex	Oatmeal	Spaghetti
Cornmeal, yellow	Macaroni	Ralston	Tapioca
Farina	Matzoth, unsalted	Rice	Wheat, shredded
		Rice, puffed	Wheatena

NUTS, UNSALTED

Almonds	Chestnuts	Peanuts
Brazil	Pecans	Walnuts

BEVERAGES

Coffee, clear	Tea, clear	Milk (low sodium)
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SEASONINGS

Allspice	Garlic	Paprika	Vanilla
Bay	Mustard, dry	Pepper	Vinegar
Caraway	Nutmeg		

SWEETS

Honey	Jam	Jelly	Maple syrup	Sugar
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Practically all foods contain sodium. The natural content, however, varies widely, animal foods, in general, containing significant amounts, while plant foods contain relatively little. One of the dangers of diets restricted in sodium is that they are apt to be too low in milk. A diet with a moderate restriction of sodium would permit at least 2 cups of milk but on more limited diets a sodium-deficient milk even though more expensive is necessary. Fresh milk contains about 122 milligrams of sodium per cup while the modified low-sodium milk contains only about 40 milligrams per cup. The present trend is toward a diet with a moderate restriction in sodium.

There is danger of taking too little sodium chloride and no one should attempt to maintain a low-sodium diet without the supervision of a physician. This danger is increased in hot weather. The popular fad of losing weight by restriction of table salt will be disappointing, since the restriction of sodium in this way brings about a loss of water and not tissue. The water is soon replaced in response to thirst.

Potassium is abundant in both plant and animal tissues and does not need to be given special consideration in the normal diet. How-

ever, a deficiency may occur with prolonged loss of appetite, in fasting, or in starvation. It is an essential intracellular constituent. Cannon, Frazier, and Hughes showed that the removal of potassium from an otherwise adequate diet for rats led to poor food consumption, failure to gain weight, development of cardiac lesions, and death.

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Calcium, Phosphorus, and Magnesium

The body is constantly losing some of each nutritionally essential mineral element. It becomes necessary to replace the loss through diet, or health will not be maintained. For the adult, whose tissues are fully formed, it is only necessary to make good the "wear and tear"; for the growing organism there must be, as in the case of protein, an additional "growth quota" to foster the construction of new body substance at a proper rate.

In order to administer the diet intelligently, we need to know as much as possible about the requirements for various mineral elements, both in childhood and adult life. For some elements, as calcium and phosphorus, the amount needed daily is relatively large, and on this account there is possibility of serious shortage, especially of calcium, unless food is chosen with discrimination; for others, as iron, the portion needed day by day is very minute, but the quantities in food materials are also minute, and an intake below the optimum is likely to occur if the matter is left entirely to chance. Practically we shall find that if the requirements for calcium, iron, and iodine are met there is little likelihood of the other mineral elements being inadequately furnished, since the foods which supply these elements along with adequate protein will also provide the other essential mineral elements.

Section 1. CALCIUM

Significance in Normal Nutrition

The role of calcium as body-building material is obvious and striking. The rigidity of the bony framework of the body is in real contrast to the softness of other tissues and is clearly related to the presence of calcium in the bone. The same is true with regard to the teeth. Approximately 99 per cent of the calcium in the body is found in the bones and teeth. Not so readily apparent, but of great significance, is the part played by this element in the regulation of body processes. Some of the ways in which it functions have already been mentioned: viz., the control of the contractility of muscles, and particularly the rhythmic beat of the heart; the preservation of the normal response of nerve tissue to stimuli; and the coagulating power of the blood. In addition to these very important functions, calcium is a kind of coordinator among the mineral elements. These must be nicely balanced in order that all parts of the body may function successfully; if sodium, or potassium, or magnesium, for instance, should tend to be too much in the ascendancy, calcium is capable of correcting the disturbance which might result, whether it be in the direction of increased or decreased irritability. This ability of calcium to correct disturbances of equilibrium was pointed out by Meltzer in 1908.

In adults, the bones serve as a reservoir of calcium, which can be drawn upon to maintain the level of calcium in the blood with no immediate damage to the bone other than the weakening consequent to withdrawal of some of the supporting calcium phosphate. Bone trabeculae, which are crystals of calcium compounds, grow from the inner surface of the ends of the bones toward the center of the cavity. This increases the area of bone salt material with which the blood comes in contact as it circulates through the vascular ends of the bones. That adult bone is a dynamic substance and is constantly undergoing reconstruction has been demonstrated by the use of radioactive calcium which makes it possible to trace the pathway of the element as it circulates through the body.

In the young, calcium is needed for the developing bones and teeth. Any deficiency in the calcium supply or any disturbance of the conditions under which the bone is able to store calcium results

in weakened bones, contracted thorax and pelvis, defective teeth, and otherwise stunted growth.

In studies on rats, Sherman demonstrated that higher levels of calcium in the diet increased the length and density of the skeleton, delayed the onset of degenerative changes, and at the same time provided greater vigor and increased the life span of the rat.

Calcium Requirement of Adults

The calcium requirement must be studied by taking account of the calcium in food, urine, and feces in carefully planned experiments. The first extensive review of studies made to establish the calcium requirement was reported by Sherman in 1920. The average of 97 experiments indicated that the calcium requirement of adults is about 0.5 gram of calcium per day. Since that time many studies have been published which call attention to a number of problems arising in the determination of the calcium requirement.

The adult, for example, appears to be able to adjust to lowered intakes of calcium as shown in studies of population groups in the tropics and semitropics where sunshine is plentiful but food calcium limited. Sherman, however, suggests that in the cases which have been carefully studied, the people utilize sources of calcium which we neglect, or in the course of their lifetime, are handicapped by their low calcium intakes. The question which comes to mind is: Although they may appear to get along on less calcium, are they as well off?

A recent report from Formosa illustrates the desirability of knowing more about food practices. The diet of the natives had been reported to be very low in calcium although no evidence of calcium deficiency had been found during a thorough clinical investigation. A study of the foods brought out the interesting fact that the millers in Formosa have a practice of adding what they call "stone powder" to the rice during the milling process. The "stone powder" is essentially calcium carbonate and is used to whiten the undermilled rice. This brings the calcium in the cooked rice to about 225 to 450 milligrams per pound. Since rice is the chief source of calories a large portion of the calcium needed is obtained in this way.

Calcium balance studies tend to reflect the previous dietary intake of calcium and to show intermittent fluctuations (losses and gains) of calcium. The utilization of the calcium of ingested food varies tre-

mendously among individuals and may be related in part at least to the composition of the rest of the diet. All of the studies show that there is a wide variation in the calcium requirement of adults. The weight of the skeleton increases in the adult until about age thirty-five and then decreases with yearly fluctuations until about age sixty-five, and from then on during advanced years it decreases progressively. Urinary losses in older individuals are apparently increased.

In a recent review of the calcium requirement by Ohlson,¹ attention is called to the extensive records of calcium balance days (over 17,000) on adults of all ages which have been reported in the literature. This represents a truly amazing amount of work on human subjects and gives some idea of the amount of research on calcium which backs up the current recommendation of the Food and Nutrition Board of the National Research Council of 0.8 gram of calcium per day for men and women irrespective of differences in weight. This allowance of 0.8 gram of calcium per day provides for a good margin of safety above the actual requirement.

Osteoporosis in older people apparently is not entirely related to the calcium intake. The failure of the protein matrix in which calcium is deposited and the general atrophy occurring as one grows older are also concerned in the decalcification of the skeleton. Stare in reporting on X-ray studies on adults past the age of forty-five to fifty years called attention to the extensive demineralization of bone. This and the fact that calcium may be less efficiently utilized in older people point to the desirability of a liberal calcium intake. Vinther-Paulson in Denmark studied 38 patients sixty-eight to ninety-six years old living in institutions. Dietary studies showed that the daily calcium intakes varied between 0.2 and 1.1 grams per day. Among those with intakes of 0.5 gram or less, 74 per cent showed decalcification as demonstrated by X-ray studies. Those with intakes of 0.8 gram or more showed no evidence of bony changes. As has been emphasized by Albright, the failure to get adequate calcium and phosphorus from milk and cheese may also lead to deficient protein intake.

The calcium requirement of women is greatly increased by pregnancy and lactation. During pregnancy the mother must provide a

¹ Ohlson, M. A. "The Calcium Controversy." *Journal of the American Dietetic Association*, Vol. 31, page 333 (1955).

store of calcium upon which the fetus draws for the development of its skeleton. Lusk cited a study of the calcium retention of a mother and fetus for 23 weeks in which it was calculated that the mother retained only 4.2 grams, but the fetus retained 30.12 grams, or over seven times as much. The weekly additions to the calcium of the fetus at different periods were estimated as follows:

<i>Week of Pregnancy</i>	<i>Calcium Added per Week, Grams</i>
16	0.41
21	0.43
29	2.09
40	2.09

The Food and Nutrition Board of the National Research Council recommends a daily dietary allowance of 1.5 grams of calcium for the third trimester of pregnancy. This allowance is intended to provide liberal levels of calcium for the growth of the fetus and is based on the extensive observations of Macy and co-workers, Coons, and others. It should be kept in mind that every young girl should continue to have a quart of milk daily on through the child-bearing period in order to provide the best calcification for her offspring as well as for her own protection. In cases where the previous diet has not followed a pattern of this kind the practice of taking a quart of milk daily should start as early in the period of pregnancy as possible.

During lactation the mother has to supply for months the calcium required by a rapidly growing infant. From the average milk intake of breast-fed babies it may be estimated that the mother will furnish in her milk approximately the following amounts of calcium:

WEEKLY CALCIUM CONSUMPTION OF INFANTS

<i>Age, Months</i>	<i>Calcium in Milk, Grams per Week</i>
3	1.9-2.2
6	2.5-2.7
9	2.7-3.0

Macy, at the Children's Hospital of Michigan in Detroit, made a long study of three women during the entire reproductive cycle. They were housewives who were supplying milk to the mother's milk bureau of Detroit. They were living in their own homes, taking care of their families, and eating their own freely chosen diets. All were

able to secrete large quantities of milk and all took large quantities of cow's milk as a beverage, so that it supplied three-fourths or more of the total calcium and half or more of the total phosphorus of the diet. The total intake of both calcium and phosphorus usually exceeded 3 grams per day and ranged up to 4 grams. In their first and second lactation periods these amounts were enough to keep them in calcium equilibrium for the most part, but in their third and fourth lactation periods, it became more difficult to maintain equilibrium even when cod liver oil was added to the diet with the object of securing better utilization of the calcium. These women were putting their capacity for milk production to an unusually severe test, but the findings impress us with the importance of a very liberal intake of milk to provide calcium for the nursing mother, and the use of cod liver oil to promote calcium and phosphorus utilization. The allowance recommended by the Food and Nutrition Board of the National Research Council for the period of lactation is 2 grams of calcium daily for a milk production of 850 milliliters (about $\frac{7}{8}$ quart).

Calcium Requirement of Children

In view of the constructive and regulatory functions of calcium, it is important that the growing organism be at all times liberally supplied with this element. The serious handicap of calcium shortage during the period of growth is readily demonstrated in experimental animals. The two rats in Fig. 43 were of the same litter, weaned from a mother on a normal diet at the age of four weeks and then put, one on a diet inadequate in protein, the other on a diet lacking calcium. That the results of a deficiency of calcium are quite different from those of a shortage of protein is well exemplified by the comparison of these two animals. While both are stunted to the same degree, the low protein diet permitted more growth of the skeleton and interfered less with health, so the animal on this diet is sleek and slim in contrast to the short, stocky rat on the diet lacking calcium.

The effect of the lack of calcium on the rate of growth will be best appreciated by comparing the calcium-deficient animal's weight record with that of one fed an adequate diet. In Fig. 44, the animal on the normal diet weighed at the age of fourteen weeks more than two and a half times as much as did his litter brother deprived of

calcium. The animal on the diet lacking calcium was not only smaller and weaker than its brother on a normal diet, but its fur was rough and thin and it suffered from nasal hemorrhages in addition to severe skeletal deformities.

Such experiments impress upon us the importance of calcium for the growing child. During the period of growth a white rat, which will have multiplied its birth weight about 70 times when fully mature,



Fig. 43. Two rats placed at four weeks of age on restricted diets and photographed at the age of sixteen weeks. The one on the left had only half enough protein, the one on the right was deficient in calcium. Both weigh the same (60 grams). The control on an adequate diet weighed 216 grams at this time. Note the short, smooth fur and slender form of the low-protein rat, and the long, bushy fur and very short body of the calcium-deficient rat.

will increase the calcium content of its body about 340 times. Such figures bear ample testimony to the need for a liberal supply of calcium during the whole period of growth.

A careful study of the calcium requirement of children was made by Sherman and Hawley in 1922.² Altogether 417 experiments were conducted on 21 healthy children from three to fourteen years of age. In one series, on 3 children, four, five, and twelve years of age respectively, extending over 48 days, the calcium was kept at different levels in successive periods by changing the amount of milk in the diet, in order to find out what daily allowance of milk would induce the best calcium storage. In the case of all 3 children the best utilization of calcium was found when approximately a quart of milk a day was included in a simple mixed diet. The relationship between the milk and the calcium storage is shown in Fig. 45.

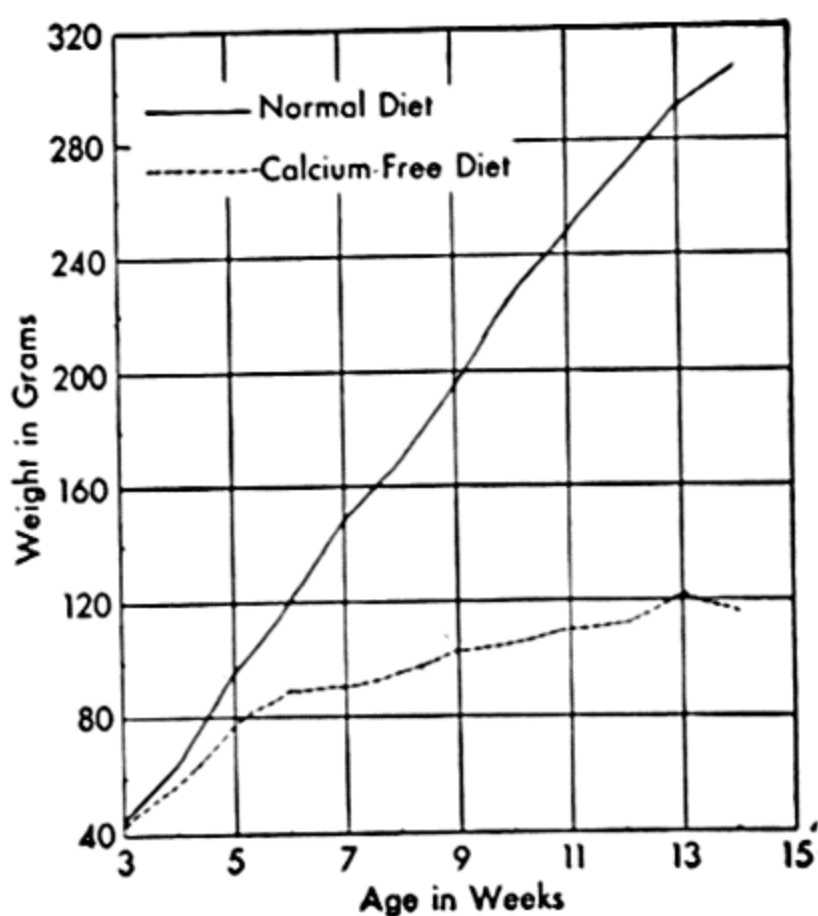


Fig. 44. The upper line represents the growth record of a rat fed an adequate diet from weaning at the age of four weeks; the lower, that of a litter brother fed a diet lacking calcium.

Later studies have served to confirm these findings. Stearns and Jeans,³ at the State University of Iowa, gave children four to twelve years of age diets in which the calcium was adjusted to be equivalent to that in either 1 pint or 1 quart of milk, and found as a rule considerably higher retentions with the larger calcium intake. They also noted that there was better retention when calcium and phosphorus were given together than when some source of calcium was used which did not furnish phosphorus, such as calcium carbonate, giving additional evidence of the practical value of milk, in which these two elements are both well represented.

² Sherman, H. C., and Hawley, E. "Calcium and Phosphorus Metabolism in Childhood." *Journal of Biological Chemistry*, Vol. 53, page 375 (1922).

³ Stearns, G., and Jeans, P. C. "Utilization of Calcium Salts by Children." *Proceedings of the Society for Experimental Biology and Medicine*, Vol. 32, page 428 (1934).

The most striking confirmation of Sherman and Hawley's work is that of Daniels ⁴ and her associates at the Iowa Child Welfare Research Station, who made a careful study of the calcium needs of

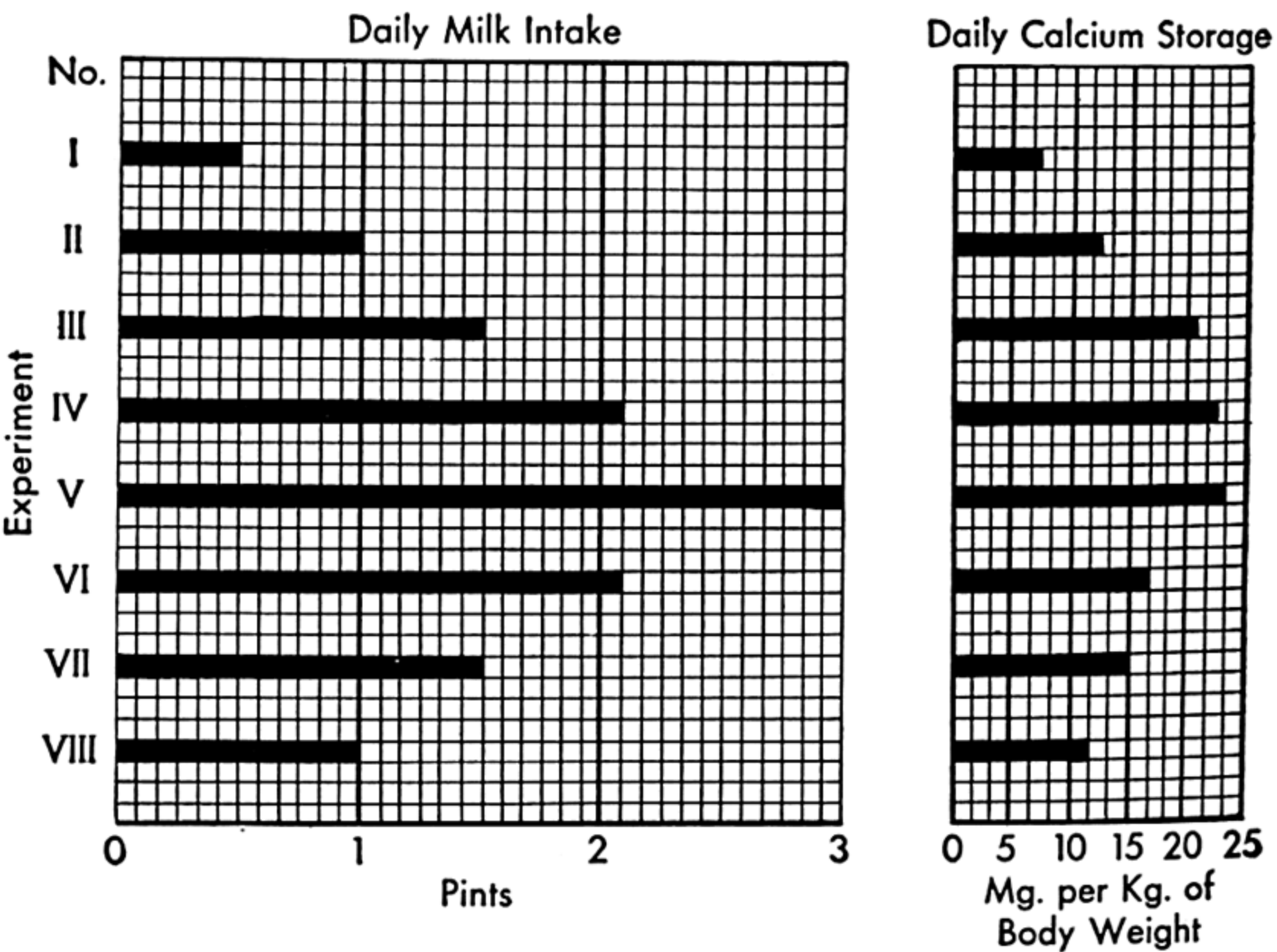


Fig. 45. This chart shows a series of 8 experiments of 6 days each in which the calcium intake was systematically varied from period to period by changes in the amount of milk. The very definite response to increased milk intake is shown in the above record of calcium storage of one of the children, a 12-year-old girl.

preschool children under such dietary conditions as are prescribed today by the best nursery school nutritionists. They answered the question as to whether the children studied in 1922 had sufficient vitamin D for the best calcium storage. Each child in their group of two girls and eight boys, three to five years of age, received twice daily a ten-minute exposure to the rays of a sun lamp and once daily a teaspoonful of cod liver oil with additional viosterol. This not only assured ample vitamin D but likewise vitamin A, which also favors calcium storage. Orange juice twice daily provided an excellent supply

⁴ Daniels, A. L., Hutton, M. K., Knott, E. M., Wright, O. E., and Forman, M. "Calcium and Phosphorus Needs of Preschool Children." *Journal of Nutrition*, Vol. 10, page 373 (1935).

of vitamin C, which aids in the retention of calcium. The choice of foods was such that the children receiving a pint of milk daily were getting as much total calcium as those in the Sherman and Hawley study who received a pint and a half (750 cc.) of milk, the total daily intake of the Daniels group being 0.77 to 0.90 gram of calcium, and of the Sherman and Hawley group 0.74 to 0.92 gram for the same ages. This was sufficient to give daily retentions of the same magnitude as in the Sherman and Hawley study, mostly between 9 and 12 milligrams per kilogram. In both studies the difference between intakes of about 1 gram per day and more did not make any marked increase in storage, as is shown in Fig. 45 by comparing periods III, IV, and V. Hence the dietary standard of 1 gram of calcium per day would seem very well established. The dietary allowances recommended for children by the Food and Nutrition Board of the National Research Council will be found in Table III(a) in the Appendix.

The question as to what a child can profitably use cannot be answered by any short-time experiment. We are concerned not only with well-being from day to day but also with effects on future health. In order to discover whether there are any real gains from some surplus of calcium over what appears to result in good storage, Sherman and Campbell⁵ have observed the effect on rats of two diets differing in calcium content through many generations. The first diet consisted of five-sixths ground whole wheat and one-sixth dried whole milk with added common salt and distilled water to drink. On this diet rat families have prospered for over 80 generations, hence there is no doubt that it is an adequate diet. The second diet differed from the first only in the addition of calcium carbonate to make the calcium intake equal to that in a quart of milk instead of a pint.

On the calcium-enriched diet, growth was somewhat more rapid and average size at a given age somewhat greater. The appearance and behavior of the adult animals indicated that the more liberal calcium intake resulted in a higher vitality which was maintained over a long period of time. The females matured somewhat earlier, showed a longer period of ability to bear young, and reared a higher percentage of them. The males, not having the strains of maternity,

⁵ Sherman, H. C., and Campbell, H. L. "Effects of Increasing the Calcium Content of a Diet in Which Calcium Is One of the Limiting Factors." *Journal of Nutrition*, Vol. 10, page 363 (1935).

manifested their greater vigor by longer life and a longer period between the attainment of maturity and the onset of senility. Thus, improved growth, greater adult vitality, lowered death rates, and increased length of life show that the increased calcium improved the nutritive value of a diet which by all ordinary signs would be adjudged adequate.

"In human nutrition," Sherman⁶ points out, "the enrichment of the diet in calcium should normally be accomplished, not by the use of calcium salts as such, but rather by increasing the consumption of calcium-rich food, especially milk, which contains along with its abundant calcium content, such proportions also of phosphorus and other mineral elements as to insure improvement of the dietary in its mineral content as a whole."

Food Sources of Calcium

For the most part we are dependent on milk and milk products to supply us with the daily allowance of calcium. One pint of milk daily for each adult and 1 quart for each child will, along with the small amounts of calcium in vegetables, furnish the daily recommended allowance. See Fig. 46 for a comparison of foods as sources of calcium.

Cheeses are generally considered good sources of calcium but the different varieties vary greatly. The reader is referred to the tables in the Appendix for calcium values of cheeses (see Tables II and IV) and to Chapter 20.

The availability of the calcium of a number of vegetables has been investigated. Thus far it seems safe to say that the calcium of carrots, almonds, kale, Chinese cabbage, celery, cabbage, turnip greens, collards, lettuce, string beans, leeks, rutabaga leaves, cauliflower, and broccoli is well utilized. That of spinach, beet greens, and sorrel, because of the oxalic acid present, is, for all practical purposes, not to be counted upon at all. Fruits in general are poor sources of calcium.

Since such a limited number of foods can be relied upon to furnish significant amounts of calcium, the sources of calcium in the diet must be selected with discretion. Certainly there is little danger

⁶ Sherman, H. C. *Chemistry of Food and Nutrition*, 7th edition, page 269. The Macmillan Co. (1946).

of excessive intakes of calcium from foods. The findings of various dietary surveys furnish evidence that calcium is the mineral element most likely to be deficient in the human dietary.



Fig. 46. Food Portions Yielding 25 Milligrams (One Share) of Calcium

	<i>Grams</i>		<i>Grams</i>
Cauliflower	111	Milk, whole	21
Peas	111	Milk, evaporated	10
Cabbage, headed	56	Cheese, Cheddar	3
Beans, string	38	Almonds	10
Carrot	63	Clams	26
Celery	50		

Section 2. PHOSPHORUS

Phosphorus is indispensable for all active tissues of the body (both the skeletal and soft tissue), being concerned in cell multiplication and cell movement and the maintenance of the proper liquid content of the tissues. It also plays an important part in regulating the neutrality of the blood and is essential for the chemical changes by means of which the energy-yielding nutrients are oxidized and their energy liberated at just the rate demanded by the needs of the organism.

Because phosphorus is essential to all body tissues, the growth of new body substance involves the retention of a certain amount, just as it does a storage of protein. The greater part of the retained

phosphorus is deposited in the bones along with calcium as calcium phosphate. If conditions during growth are not favorable for the deposition of calcium phosphate in the bones, we have the disease known as rickets, which will be discussed in detail later. One of the notable advances in the study of rickets was the observation that it is characterized by a low phosphorus content of the blood. After that it was demonstrated that rickets could be produced experimentally by feeding a diet low in phosphorus.

Sherman, in 1920, from consideration of extensive work in his own and other laboratories on the phosphorus requirement of adults, concluded that the adult needs daily an average of 0.88 gram per 70 kilograms of body weight. He recommended a 50 per cent margin as a "contingency fund" to allow for individual differences in utilization and fluctuation in the amounts found in food and suggested a dietary standard of 1.32 grams of phosphorus per man per day. This is in line with the 1953 recommendation of the Food and Nutrition Board of the National Research Council of a phosphorus allowance for adults of approximately one and one-half times that for calcium.

An extensive study of the phosphorus requirement of children was made by Sherman and Hawley in 1922. They took 12 children ranging in age from three to thirteen years to a country home for convalescent mothers, where they could be supervised day and night, and kept account of all food eaten and of all excreta. Some of the children were under this close observation as long as 84 days. From analysis of the data so collected, the authors concluded that the child needs for optimum growth about 1 gram of phosphorus per day up to the age of fourteen years. Many additional studies have been made since that time and the results indicate that the phosphorus allowances should be at least equal to those for calcium in the diets of children. This is approximately 1 gram for children up to nine years of age with slightly higher levels for older children.

Phosphorus is so widely distributed in foods that the intake of phosphorus in our daily foods usually exceeds that of calcium, except in the case of infants and small children whose diets are mostly milk. Since it is now well established that a dietary of everyday foods which furnishes sufficient energy, protein, calcium, and iron can be depended upon to furnish also sufficient phosphorus, it is no longer considered necessary, under ordinary circumstances, to calculate the phosphorus.

Section 3. MAGNESIUM

Magnesium is so abundant in plant and animal foods that there is little likelihood of an insufficient supply in any ordinary mixed diet. A magnesium-free diet is difficult to prepare, even for experimental purposes. Rats grow to maturity when very little is present in their food. That its presence is not without significance, however, is indicated by some experiments of McCollum and associates with a practically magnesium-free diet. On this diet the animals failed to grow and manifested skin disturbances and nervousness to so great a degree that the mere rustling of paper was sufficient to cause convulsions and death. The bones of these animals showed increased calcification. Other workers have reported increased calcium in soft tissues of animals on very low magnesium intake, especially in the kidneys where the calcium level was about $12\frac{1}{2}$ times that in the control animals. Other animals including dogs, calves, and rabbits have been found to show similar symptoms on a magnesium-deficient diet. It is apparent from these findings that a deficiency of magnesium disturbs calcium metabolism, although just how this comes about is not clear.

Like phosphorus, magnesium is a component of soft tissues as well as of bone, about 75 per cent of the magnesium in the body occurring in combination with calcium and phosphorus in bone salts and the remainder in the soft tissues and fluids. Like potassium, it is an important mineral element in the intracellular fluid and appears to serve as a catalyst for certain enzyme reactions.

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Iron, Copper, Cobalt, and Other Trace Elements

Section 1. IRON

Iron was discovered in prehistoric times and was considered to have some therapeutic value which continued to evoke medical interest. Early in the eighteenth century it was recognized as a constituent of the blood. Long before the importance of calcium and phosphorus in vital processes was fully appreciated, the connection between iron in blood and the oxidative processes in the body had been discovered. Lavoisier made the mistake of thinking that oxidation took place in the lungs, but before his death a mathematician, Lagrange, considering that the temperature of the lungs was not higher than that of the rest of the body, expressed the conviction that oxygen "dissolved" in the blood and that heat might be generated wherever the blood carried oxygen. It was not until 1838, however, that the Swedish chemist, Berzelius, showed that the red coloring matter of blood was capable of absorbing much oxygen and concluded that this was due to the iron in this pigment. We now know that we have in the adult human body about 25 million times a million red blood corpuscles, owing their color to the iron-bearing protein, hemoglobin, and through its agency the red blood corpuscles transport oxygen through all the intricacies of arteries and capillaries to the innermost cells of every organ and tissue.

In 1889, Bunge reported the case of a young man who developed anemia on a diet of milk only. He also found that mice so fed became anemic, and that although the obvious explanation was the

small amount of iron present in milk, the cure was not so simple, inasmuch as the addition of a pure iron salt had but little effect. Since much better results were obtained with egg yolk, Bunge concluded that the difference was due to the peculiar chemical union of the iron with protein in the egg yolk. A few years later Abderhalden,¹ in a critical review of the work of Bunge and others, summarized the knowledge of that period as follows: "The mere fact that the addition of iron to nutriment poor in iron does not have any distinct influence upon the formation of hemoglobin, in no way speaks against the participation of inorganic iron in the synthesis of hemoglobin in the case of normal nutrition, but it indicates that other building material is wanting as well as iron."

For many years the controversy as to the relative value of organic and inorganic iron continued, and it was not until 1927 that it was clearly demonstrated that inorganic iron could be used to form hemoglobin if adequate quantities of copper were also present.

Significance in Normal Nutrition

Not only in the red blood corpuscles, but very generally in active cells, both animal and vegetable, we find iron as an essential part of the chromatin substances in the cell and functioning as a stimulator of the vital processes of the cell. Therefore, as a carrier of oxygen and as an activator of cell functions, iron has significance out of all proportion to the amount in the body—between 3 and 5 grams. The greater part of the iron in the body is found in the hemoglobin of the red blood cells. While the blood constitutes only about 7 per cent of the total body weight it contains 55 to 60 per cent of the iron in the body.

In addition to being essential for the formation of the hemoglobin of the red cells (erythrocytes) iron is also essential for myoglobin (muscle hemoglobin). It is important in tissue oxidation-reduction reactions and has been found to be essential for certain body enzymes, for example, the cytochromes. The myoglobin and enzymes contain only about 10 per cent of the total iron in the body.

In 1937, Laufberger, a French scientist, isolated a new crystalline

¹ Abderhalden, Emil. *Textbook of Physiological Chemistry*, translated by Hall, page 398. John Wiley and Sons (1908).

protein from horse spleen which was given the name ferritin. This protein substance was found to contain 23 per cent (dry weight) of iron and has as one of its chief functions that of storage of iron in the liver. This substance furnishes a readily available source of iron which can be mobilized as needed for hemoglobin synthesis. Studies on dogs in which radioactive iron was injected intravenously showed that 80 per cent of the iron administered was recovered in the form of ferritin in the liver.

Ferritin also plays a role in the absorption of iron by the mucosa of the intestinal tract. According to Granick, the mucosa cells apparently contain a protein (apoferritin) which combines with the iron released from the chyme (digested food) in the small intestine, forming ferritin. The iron from the ferritin passes into the blood stream if the blood serum level is low, but if the blood serum level is not sufficiently low, no iron is absorbed from the intestinal tract. This has been described as the "shutter" mechanism of iron absorption. Anemic dogs and rats have both been found to absorb more iron than normal animals. Ferrous iron appears to be more readily absorbed by humans than ferric but dogs can absorb either ferrous or ferric iron equally well.

Iron is also stored in the body in the form of hemosiderin. The intracellular deposits of ferritin and hemosiderin are found in the bone marrow, spleen, and liver. It is estimated that these storage depots contain 30 to 35 per cent of the total iron in the body. The red blood cells have an average life of four months. When old worn-out red blood corpuscles are finally disintegrated most of the iron is retained for resynthesis, practically none being excreted in the urine and only small amounts being eliminated in the feces. Using radioactive iron to determine the amount of iron lost in the intestinal tract, Moore at Washington University School of Medicine studied the effect of tracer doses on a number of normal individuals for a total of 360 days and found no large excretion of iron at any time. The human organism has been described as a "tight compartment" as far as iron is concerned.

There are many unsolved problems in connection with the metabolism of iron and the mechanisms involved need to be further elucidated by research. See Section 2 of this chapter for the discussion of the relationship of iron and copper.

Iron Requirement of Adults

Studies of iron requirement are difficult to make. Periods of observation need to be long and the analytical techniques require skill and the most meticulous care. In 1935 an unusually long study of the iron requirement of adult men was reported by Farrar and Goldhamer² of the University of Michigan. One man lived for 316 days on a practically uniform diet, consisting of milk, cream, bread, butter, jelly, shredded wheat, canned grapefruit, and distilled water, and during the last month of this regime maintained iron balance on 5.2 milligrams of iron daily.

This is in close agreement with a study by Sherman of a man on a diet composed of bread and milk exclusively. Here, as in the earlier work of von Wendt and the later work of Orten, Smith, and Mendel, there is indication that a liberal calcium content of the diet conduces to efficient use of iron. Other investigators using similar techniques have reported iron requirements ranging from 3.7 to 11 milligrams. From consideration of the data available at the end of the year 1940, Sherman³ concluded that the average requirement is about 8 milligrams per day. Since then Leverton⁴ has reported a study on four young women who maintained iron balance on intakes of about 7 milligrams while Houghton⁵ obtained iron balance in two women on an average intake of just over 4 milligrams. Moore concludes as a result of his long-time studies on normal individuals using radioactive iron that the normal male requires less than 10 milligrams per day to remain in balance.

As in the case of calcium and phosphorus, it is important that there should be a good margin of safety in a recommended dietary allowance for iron. One reason for a generous surplus of iron is that many minor disturbances in the body cause loss of iron and there are no large reserves to draw upon as in the case of calcium and

² Farrar, G. E., and Goldhamer, S. M. "The Iron Requirement of the Normal Human Adult." *Journal of Nutrition*, Vol. 10, page 241 (1935).

³ Sherman, H. C. *Chemistry of Food and Nutrition*, 6th edition, page 288. The Macmillan Co. (1941).

⁴ Leverton, R. M. "Iron Metabolism in Human Subjects on Daily Intakes of Less Than Five Milligrams." *Journal of Nutrition*, Vol. 21, page 617 (1941).

⁵ Houghton, D. "The Utilization of Iron from Foods Studied by Two Methods." *Dissertation*, Columbia University (1942).

phosphorus. Infections, however mild, are a common cause of iron loss, and the individual taking just enough to maintain equilibrium may, as Dr. George R. Minot,⁶ one of the recipients of the Nobel Prize for his work on pernicious anemia, says, "be precipitated into the zone of partial deficiency by the advent of infection." There are also measurable losses of iron through the skin in perspiration, the hair, the fingernails, and the toenails.

Losses of iron in menstruation have been determined by Leverton and Roberts⁷ in a long, well-controlled study of four young college women. They found losses averaging 1.7 to 3.4 milligrams per day. Moore, on the basis of his studies with radioactive iron, estimates the average menstrual loss to be in the neighborhood of 1 milligram per day. He suggests that to compensate for this loss a woman needs to take between 15 and 20 milligrams of iron per day. Sherman has suggested that these higher requirements for women may be offset by the lower body weights of women and that it is therefore safe to use the same allowance for both men and women. Adding a 50 per cent "factor of safety" to the average requirement of 8 milligrams gives a dietary standard of 12 milligrams daily. This is the allowance recommended by the Food and Nutrition Board of the National Research Council.

A diet which covers the losses of menstruation will go far toward meeting the needs of pregnancy because what was formerly lost will be available for the fetus. However, there must be iron not only for its normal development, but to enable it to accumulate a reserve for use during the first few months of life. And also there is frequently in pregnancy a decreased secretion of acid in the stomach which tends to interfere with iron absorption. It has been noted often that many women in the later weeks of pregnancy have a low blood hemoglobin. Some light is thrown on the capacity of the mother to store iron by a study by Coons,⁸ at the Oklahoma Agricultural Experiment Station. For 101 days the same diet was eaten, and for 82 days the food

⁶ Minot, G. R. "The Anemias of Nutritional Deficiency." *Journal of the American Medical Association*, Vol. 105, page 1177 (1935).

⁷ Leverton, R. M., and Roberts, L. J. "The Iron Metabolism of Normal Young Women during Consecutive Menstrual Cycles." *Journal of Nutrition*, Vol. 13, page 65 (1937).

⁸ Coons, C. M. "Some Effects of Cod Liver Oil and Wheat Germ on the Retention of Iron, Nitrogen, Phosphorus, Calcium, and Magnesium during Human Pregnancy." *Journal of Nutrition*, Vol. 10, page 289 (1935).

was weighed and collections of excreta made. The diet furnished from 18 to 20 milligrams of iron per day, and storage amounted to from 2 to 6 milligrams. When wheat germ or wheat germ ash was added to raise the iron intake to 24 to 28 milligrams, the storage increased, approximating 7 to 9 milligrams as a rule, but in two different periods it rose to about 11 milligrams. This study seems to indicate that 20 milligrams or more per day can be profitably used by pregnant women in the latter half of pregnancy when fetal growth and fetal storage are approaching their maximum. Hahn and associates in 1951 also found that additional iron was of greater importance in the last half of pregnancy. A safe iron allowance for pregnancy and also for lactation would seem to be not less than 15 milligrams per day, which is the allowance recommended by the Food and Nutrition Board of the National Research Council.

Iron Requirement of Children

The baby comes into the world bearing in its body a special store of iron which serves as a reserve during the early period of lactation. The percentage in the infant's body at birth is about three times that in the adult's. This store has been regarded as sufficient to compensate for the low iron content of mother's milk through the first few months of life. Many recent studies have shown that, especially with the artificially fed baby, a higher level of hemoglobin is maintained if some special source of iron, such as egg yolk, a special cereal reinforced with iron, or a simple iron salt is introduced into the diet as early as the third or fourth month. A slight anemia in infants and young children, formerly regarded as unimportant, has been shown to retard growth and make the infant more susceptible to infection. When this is coupled with the fact that infection causes a considerable loss of iron, it is easy to see how a liberal intake of iron becomes a real safeguard of health. A notable study of the influence of anemia on infants was made by Mackay⁹ in London. During a five-year period over 1,000 babies under her observation were brought by mothers to the clinics of the Queen's Hospital for Children. She found that at five months of age only 10 per cent of the artificially fed and 16 per cent of the breast-fed reached a hemoglobin level of 11 grams per 100 milliliters, which she considered

⁹ Mackay, H. M. M. *Nutritional Anemia in Infancy with Special Reference to Iron Deficiency*. Medical Research Council of Great Britain, Special Report Series No. 157 (1931).

normal, although according to Elvehjem, Siemers, and Mendenhall,¹⁰ the normal content of the blood of infants between the ages of three months and one year should be between 12 and 13.5 grams. In babies of twelve and thirteen months of age Mackay found that 30 per cent of the artificially fed and 58 per cent of the breast-fed had reached the level of 11 grams per 100 milliliters. The infants with the low hemoglobin levels were not suffering from any specific disease, but nevertheless the improvement with iron treatment was marked.

An investigation to discover the best conditions for iron storage in infants was conducted by Stearns and Stinger¹¹ who found at least 0.5 milligram per kilogram necessary to secure any retention, but that it was more regular and considerably greater when from 1.0 to 1.5 milligrams per kilogram were given, whether the source of iron was eggs, an iron-enriched cereal, or a simple iron salt.

Up to 1930 there had been no effort to determine the iron requirements of the nursery school child. In that year Rose, Vahlteich, Robb, and Bloomfield made a beginning at Columbia University with a study of a two- and one-half-year-old girl. In 1934 Daniels and Wright¹² at the Iowa Child Welfare Research Station made 15 balance experiments on 8 children three to six years old, the next year Ascham¹³ at the Georgia Agricultural Experiment Station reported a study on 6 children four to six years old, and in 1941, Porter¹⁴ at Michigan State University published the results obtained in a study of 2 three-year-old and 2 five-year-old children. In these 19 children, there was equilibrium but little or no storage when the iron intake lay between 0.40 and 0.55 milligram per kilogram. Significant storage occurred on 0.60 milligram per kilogram, but retention was considerably higher when the diet furnished 0.65 to 0.75 milligram per kilogram.

These findings are borne out by the studies of Rose and Borge-

¹⁰ Elvehjem, C. A., Siemers, A., and Mendenhall, D. R. "Effects of Iron and Copper Therapy on the Hemoglobin Content of the Blood of Infants." *American Journal of Diseases of Children*, Vol. 50, page 28 (1935).

¹¹ Stearns, G., and Stinger, D. "Iron Retention in Infancy." *Journal of Nutrition*, Vol. 13, page 127 (1937).

¹² Daniels, A. L., and Wright, O. E. "Iron and Copper Retentions in Young Children." *Journal of Nutrition*, Vol. 8, page 125 (1934).

¹³ Ascham, L. "A Study of Iron Metabolism with Preschool Children." *Journal of Nutrition*, Vol. 10, page 337 (1935).

¹⁴ Porter, T. "Iron Balances on Four Normal Pre-School Children." *Journal of Nutrition*, Vol. 21, page 101 (1941).

son ¹⁵ on a group of 60 nursery school children under observation continually from 6 to 21 months, on a simple, inexpensive diet in which two-thirds of the total calories came from milk and cereals, and one-fifth from fruits and vegetables. One-half of the children had an egg added to their diet daily, with the result that the iron intake of the group receiving eggs ranged from 0.5 to 1.0 milligram per kilogram of body weight, while in the other group it fell between 0.4 and 0.7 milligram per kilogram. Hemoglobin tests were made at 4-month intervals, and out of 131 tests on children in the egg group, 40 per cent showed values of 12.5 grams or more per 100 milliliters of blood, while out of 114 tests on children in the no-egg group, only 22 per cent reached or exceeded this level. Thus while the difference in the iron intakes was small, the children having the eggs made a distinctly better record. For iron as for calcium there is a distinct advantage for the growing child in an intake which will allow a considerable surplus above the daily requirement, and since the chances of iron loss appear to be greater than those of calcium, the supply of iron should be even more liberal.

Most of our knowledge of iron requirements of older children comes from dietary studies of normal, well-nourished subjects. Koehne and Morell in their studies of girls six to thirteen years old estimated the iron (in weighed food) over a long time as from 0.37 to 0.53 milligram per kilogram. Hemoglobin tests showed that the girls were not anemic. Wait and Roberts found the intake for girls ten to sixteen years of age to range from 0.35 milligram per kilogram at ten years to 0.18 at sixteen years. Darby and his associates studied the iron absorption in school children seven to ten years of age. They found the daily intake of iron from dietary records to be about 12 milligrams. When they fed 2- or 3-milligram doses of the radioactive iron they found 10 to 16 per cent of it in the circulating blood cells. The increased absorption was attributed to the needs for growth.

Out of their evaluation of all the available data on children the Food and Nutrition Board of the National Research Council recommended the daily allowances for different ages given in Tables I(a) and III(a) in the Appendix.

¹⁵ Rose, M. S., and Borgeson, G. M. *Child Nutrition on a Low-Priced Diet*. Child Development Monographs No. 17, Bureau of Publications, Teachers College, Columbia University (1935).

The Anemias

Many types of anemia are recognized by the medical profession. Of these there are three which are of special concern to the nutrition student—nutritional or iron-deficiency anemia, pernicious anemia, and hemorrhagic anemia.

Iron-deficiency anemia, commonly called hypochromic anemia, is characterized by a low hemoglobin level. Infants under six months of age may develop this type of anemia unless, as explained earlier in this chapter, the milk diet is supplemented at least by the third month with food of high iron value. Infants and children need iron to increase their blood volume and as Moore¹⁶ suggests they undoubtedly maintain only a slight positive iron balance during their period of most active growth. The iron balance of the young woman through the period of menstruation and childbearing is precarious and unless the diet is properly safeguarded an iron-deficiency anemia may develop. A poor diet continued over a period of years or poor absorption may lead eventually to a hypochromic anemia even with normal menstruation. Women between thirty and fifty years of age are most likely to develop this type of anemia which will respond favorably to liberal intakes of iron. Ascorbic acid has been found to increase assimilation of food iron even more effectively in cases of iron deficiency than in normal individuals. Adult men and postmenopausal women are less likely to develop a nutritional iron deficiency. Gastrointestinal disturbances, such as diarrhea, deficient gastric secretion, and intestinal disease will interfere with the absorption of iron even though it is present in the food. Iron-deficiency anemia may cause striking alterations in the fingernails with a loss of luster and a flattened or concave appearance (spoken of as "spoon nails"). The skin may become dry and somewhat wrinkled. The significance of the role of a number of B complex vitamins will be discussed in the vitamin chapters.

Pernicious anemia is characterized chiefly by a deficiency of the formation of the red blood cells. Because of the prevalence of large cells it is often called *macrocytic* anemia. The hemoglobin is relatively abundant. In 1927 Minot and Murphy announced that the

¹⁶ Moore, C. V. "The Importance of Nutritional Factors in the Pathogenesis of Iron-Deficiency Anemia." *The American Journal of Clinical Nutrition*, Vol. 3, page 3 (1955).

feeding of whole liver was effective in bringing about a remission in pernicious anemia and Castle demonstrated that mixtures of beef muscle and normal human gastric juice would also produce remissions similar to those of liver feeding. Two factors were found to be involved (1) an intrinsic factor in gastric juice and (2) an extrinsic factor in foods. Years of research finally led to the discovery of vitamin B₁₂ and its effectiveness in pernicious anemia. It is now recognized that pernicious anemia patients do not produce the intrinsic factor and consequently suffer from impaired absorption of vitamin B₁₂.¹⁷ This will be discussed in greater detail in Chapter 18.

Hemorrhagic anemia results from the loss of a large quantity of blood and can be cured by providing the nutrients necessary to make up for the blood lost. In this process liver has been found to be especially effective, and meat in general better than spinach or other vegetables. Whipple and Robscheit-Robbins, in testing various foods for their effectiveness in the cure of anemia induced by bleeding, have found the following especially valuable: chicken liver and gizzard, beef liver and kidney, eggs, apricots, and raisins. All of these were superior to spinach, asparagus, and muscle meats.

Moore calls attention to the iron requirement of the blood donor. The donation in one year of 500 milliliters of blood (containing 200 to 250 milligrams of iron), just about doubles one's iron requirement. The diet of a blood donor ought to include the foods found effective in the cure of hemorrhagic anemia.¹⁸ Moore points out that in cases where one gives as many as five donations in a year, which is common, there is serious danger of an iron deficiency unless the diet is supplemented with iron salts. The food iron, which is not completely absorbed, is not adequate when the need is so great.

Foods as Sources of Iron

Many experiments have been undertaken to study the hemoglobin-producing values of food in rats made anemic by milk feeding. When a food is as good a source of iron as a pure iron salt, which induces

¹⁷ Review. "Metabolism of Vitamin B₁₂ in Pernicious Anemia." *Nutrition Reviews*, Vol. 13, page 136 (1955).

¹⁸ McKibbin, J. M., and Stare, F. J. "Nutrition in Blood Regeneration." *Journal of the American Dietetic Association*, Vol. 19, page 331 (1943).

Turner, D. F. "Dietary Recommendations for Blood Donors." *Journal of the American Dietetic Association*, Vol. 19, page 336 (1943).

a rapid and complete regeneration when fed in suitable quantity, this would seem good evidence that its iron can be readily absorbed from the alimentary tract. The results with whole wheat and oats indicate that the iron of cereals can be efficiently used. Since these foods are very inexpensive sources of iron, even the cheapest diet need not be inadequate in iron. Pye¹⁹ studied the effect of different foods on hemoglobin formation and iron retention in normal rats and found that the iron of whole wheat flour was about equal in availability to that of ferric chloride. The iron of beef liver gave almost as good results and the other foods studied, namely, beef muscle, egg yolk, kale (cooked and uncooked), and spinach (cooked and uncooked), were not quite as satisfactory.

A comparison of the availability of the iron of egg and of wheat bran in a balance experiment on two women, when the amount of iron in the diet was barely sufficient to meet daily requirement, showed equally good utilization of both.²⁰ Houghton²¹ in balance studies with two women reported no differences in the utilization of the iron from wheat germ, peas, lean beef, or ferric citrate. The long study of Rose and Borgeson, already referred to, also affords evidence of the efficiency of the iron of the egg yolk for hemoglobin formation. The results of hemoglobin determinations made at intervals of four months are shown in Fig. 47.

Moore and Dubach²² at Washington University in Missouri studied the absorption of iron from foods in healthy adult subjects by incorporating radioactive iron into the foods. They found that 14 of the 16 subjects absorbed less than 10 per cent of the iron present in eggs, chicken muscle, chicken and rabbit liver, mustard greens, and spinach. This emphasizes the need for generous portions of these foods in our daily diets since they are among the best sources of iron. Further studies need to be made of the effects of mixtures of

¹⁹ Pye, O. F. "The Utilization of Iron from Different Foods by Normal Young Rats." *Dissertation*, Columbia University (1944).

²⁰ Vahlteich, E. McC., Funnell, E. H., MacLeod, G., and Rose, M. S. "Egg Yolk and Bran as Sources of Iron in the Human Dietary." *Journal of the American Dietetic Association*, Vol. 11, page 331 (1935).

²¹ Houghton, D. "The Utilization of Iron from Foods Studied by Two Methods." *Dissertation*, Columbia University (1942).

²² Moore, C. V., and Dubach, R. "Observations on the Absorption of Iron from Foods Tagged with Radioactive Iron." *Transactions of the Association of American Physicians*, Vol. 64, page 245 (1951).

foods on human subjects. A table giving the approximate iron content of many foods will be found in the Appendix and Fig. 48

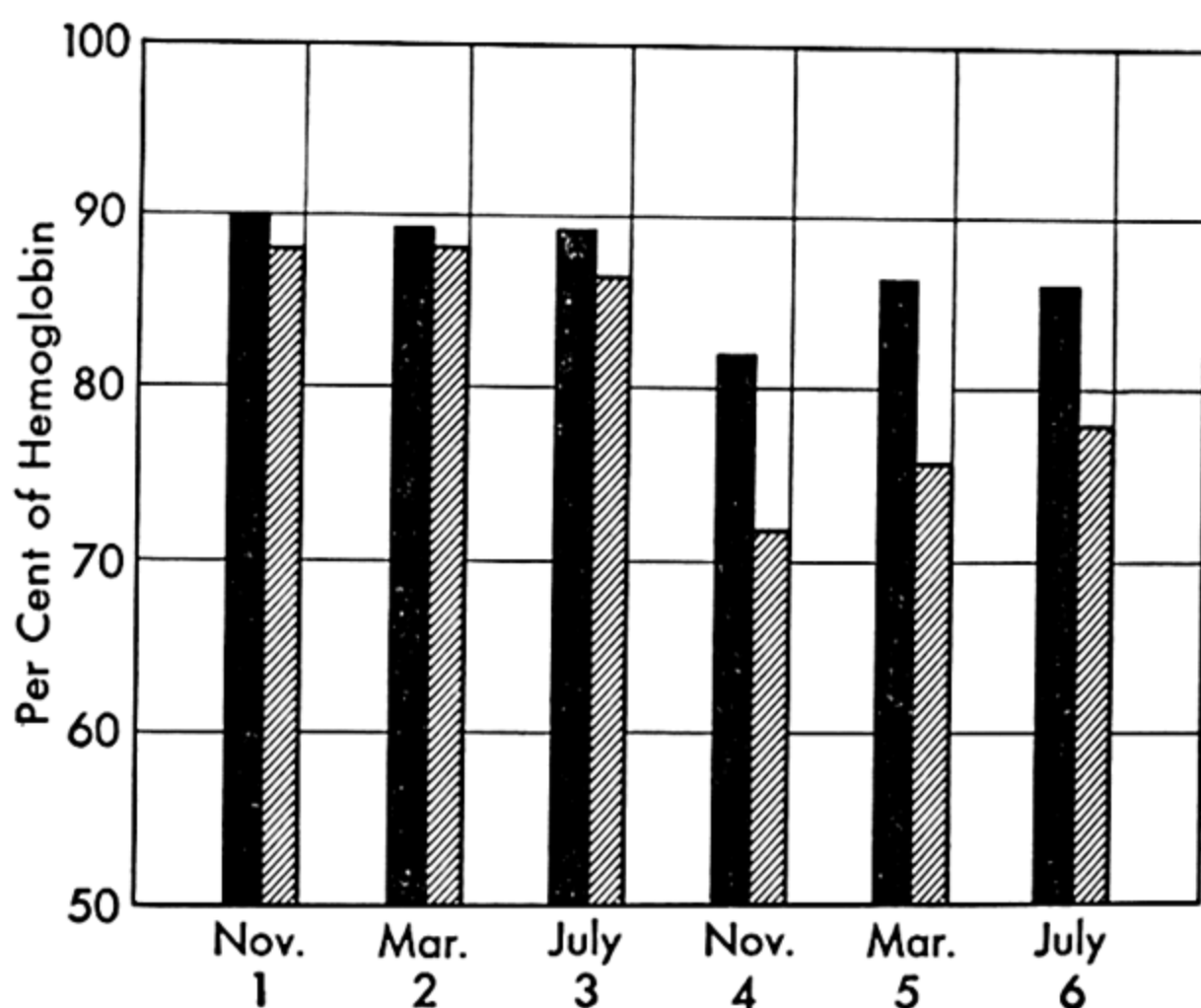


Fig. 47. Median hemoglobin values for a group of children whose iron intake was increased about 10 per cent by addition to the diet of an egg a day (solid black column) compared with a group carefully matched with them, who received no iron addition (cross-hatched column), showing a greater difference between the two groups in the second year than in the first.

shows portions of some common foods which yield approximately the same amounts of iron.

Section 2. COPPER

The presence of copper in plants was first recognized in 1816 and about thirty years later a relationship between the copper in plants and the soil in which they were grown was suggested by Deschamps. However, it required another century for its significance in animal nutrition to be clearly established.

The late Professor E. B. Hart of the University of Wisconsin and his associates started an extensive investigation in 1924 of the factors influencing hemoglobin formation. It had been recognized by earlier workers that some factor or factors in addition to iron were needed by the rabbit for the synthesis of hemoglobin. It was found that when the ash of lettuce or dried cabbage was fed to an anemic

rabbit the nutritional anemia was cured as effectively as when unashed greens were fed. This made it clear that the factor concerned must be inorganic in nature. The pale blue color often noted in some of the ash samples was suggestive of copper salts. The rabbit had been found to be not a wholly satisfactory experimental animal,



Fig. 48. Food Portions Yielding about 0.38 Milligram (One Share) of Iron

	<i>Grams</i>		<i>Grams</i>
Lettuce, loose leaf	34	Egg	14
Spinach	13	Bread, whole wheat	11
Cabbage	77	Raisins	11
Tomato	63	Beans, dried	5
Onions	77	Beef, lean	13
Prunes, A.P.	12	Oats, rolled	8
Peas, fresh	20		

partly because of its size, and consequently Steenbock, Waddell, Elvehjem, and other workers in the laboratory decided to try the effect of adding copper sulfate in addition to iron to the diet of a single rat which had been made anemic on a milk diet (see Figs. 49 and 50). The hemoglobin response was striking. Similar treatment was tried on other animals, all of which responded in the same way. It was concluded that copper was apparently a contaminant of

practically all laboratory iron preparations and trace amounts of it occurred in most natural food products, for example, dried liver, dried kidney, dried muscle tissue, wheat, and corn. Even as small an amount of copper as 1 microgram per rat per day gave a measurable response.



(Courtesy of Drs. E. B. Hart and H. Steenbock)

Fig. 49. The First Rat Made Anemic on a Diet of Whole Milk and Cured by Adding Iron and Copper to the Milk

That copper alone could play such an important role in animal nutrition was still doubted by Hart²³ and his associates. It was not until they had carried out additional studies using salts of such elements as zinc, cobalt, nickel, germanium, arsenic, manganese, and others that they were finally convinced that copper alone was effective in the synthesis of hemoglobin and could not be replaced by any other mineral element. Thus, the role of copper in the synthesis of hemoglobin was clearly established. It is now recognized as an essential element in human nutrition.

One of the problems facing these investigators in producing anemia in rats on a milk diet was the fact that milk in the process of pasteurization was contaminated with traces of copper. These traces were just enough to interfere with the development of nutritional anemia. When the copper pasteurization equipment was replaced with stainless steel this problem was eliminated and the milk was no longer contaminated with copper. About the same time the practice of using

²³ Hart, E. B., Steenbock, H., Waddell, J., and Elvehjem, C. A. "Iron in Nutrition. VII. Copper as a Supplement to Iron for Hemoglobin Building in the Rat." *Journal of Biological Chemistry*, Vol. 77, page 806 (1928).

more highly refined cereals in infants' diets was promoted. These highly refined cereals and orange juice were the only supplements added to the milk diet of infants, and a period followed when anemia in children was quite common. Now most of the infant foods are fortified with iron and copper. Also, it is common to add other foods, egg yolk and strained vegetables, earlier in the infant feeding program. Babies on human milk are better off since human milk is much higher in copper than cow's milk and it is not likely that a breast-fed infant would suffer from a copper deficiency. It is improbable that a copper deficiency would be a factor in anemia occurring in older children and adults since a diet of even mediocre quality would undoubtedly supply adequate copper. The Food and Nutrition Board of the National Research Council states that about 1 to 2 milligrams of copper daily in the diet of the adult will meet the requirement. Infants and children require approximately 0.05 milligram per kilogram of body weight. The requirement for copper is thus about one-tenth of that for iron.

Copper has been found to be essential for certain body enzymes. It has also been found to influence the actual absorption of iron when the differences are measured by using radioactive iron instead of inert iron, a technique of extreme sensitiveness. Certain other trace elements, molybdenum, lead, and zinc, have been found to interfere with the normal utilization of copper. Recent research carried out in Australia

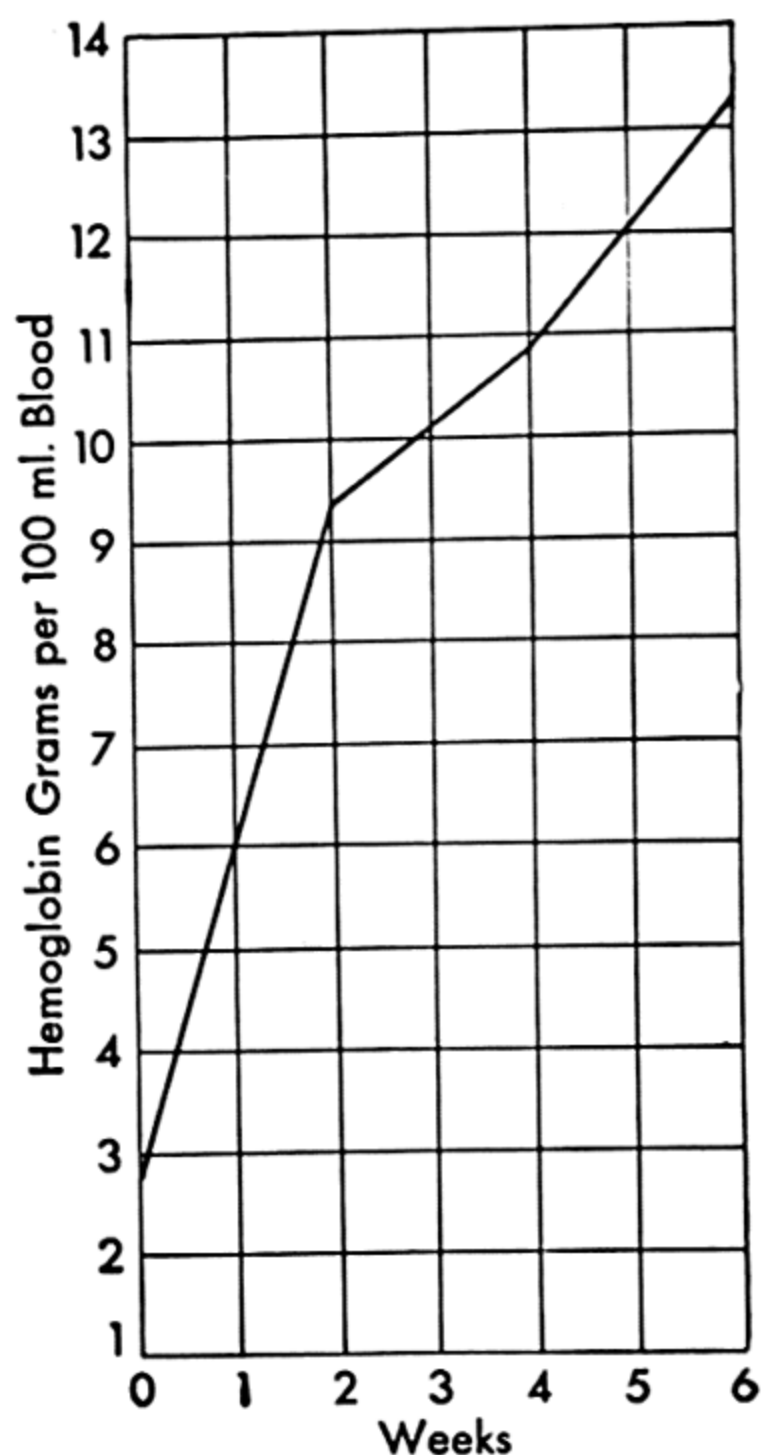


Fig. 50. Changes in the hemoglobin of the rat shown in Fig. 49, during six weeks, following the administration of iron and copper. On the milk alone, hemoglobin fell to 2.68 grams per 100 ml. of blood; after the addition of one-half milligram of iron and one-fourth milligram of copper per day it rose in six weeks to 13.3 grams per 100 ml.

shows that the effect of molybdenum on copper metabolism is related to the amount of sulfur in the diet.

Since it is not necessary to estimate copper in the ordinary mixed diet, no table of the copper content of foods is included in this book. The reader, if interested, may refer to other sources.²⁴

Section 3. COBALT

Cobalt was found to be essential in animal nutrition through the investigation of a condition occurring in sheep and cattle known as coast disease. In different localities the same condition was known by other names, bush sickness, pine disease, lakeshore disease, or simply wasting disease. The animals became emaciated, extremely listless, progressively anemic, and developed a roughness of hair, a scaly condition of the skin, and severe muscular atrophy. This condition was first described in 1909 by the Michigan Agricultural Experiment Station but it was not until 1935–36 that it was shown in Australia and New Zealand to be caused by pasturing on soils low in cobalt and that it could be cured by the administration of cobalt salts.

Ruminants (cows and sheep) apparently have the ability to utilize cobalt in inorganic form, but other animals, including man, apparently must obtain it as it occurs in vitamin B₁₂. This difference is due to the fact that in ruminants the microorganisms (flora) of the rumen can synthesize vitamin B₁₂ when enough cobalt is available, whereas in other animals and man the intestinal microorganisms cannot. Rats and chicks, for example, will show a growth response to vitamin B₁₂ but will not respond to inorganic cobalt.

An excess of cobalt in the diet of rats results in polycythemia, a condition in which the number of red blood cells and the hemoglobin are increased to about one and one-third to one and a half times the normal values. Just how cobalt brings about these results is not known as yet, but it has been found that these toxic effects of cobalt can be relieved by the administration of ascorbic acid. Polycythemia has also been developed in healthy human subjects by the administra-

²⁴ For a list of common foods as sources of copper see Taylor and MacLeod. *Rose's Laboratory Handbook for Dietetics*, 5th edition, page 265. The Macmillan Co. (1949).

tion of large amounts of cobalt, and ascorbic acid will repress these toxic effects as it does in the experimental animals (rats and rabbits).

Cobalt is like sulfur in having to be obtained in organic form. There is some evidence to show that cobalt is important in the metabolism of sulfur-containing amino acids. Its importance as it occurs in a vitamin will be discussed further in the chapter dealing with vitamin B₁₂.

It is practically impossible to prepare an experimental diet low enough in cobalt to produce a deficiency condition. Whether or not there is a human requirement for cobalt other than as it occurs in vitamin B₁₂ is not known. It is not likely that a human dietary would be deficient in cobalt.

Section 4. IODINE

Iodine has already been referred to as essential to the thyroid gland, which serves as an important regulator of the basal energy metabolism and is an indispensable factor in normal growth. It was not until 1895 that it was shown conclusively that iodine was an essential element in thyroid structure and not until 1914 that thyroxine was prepared from the gland by Dr. E. C. Kendall of the Mayo Clinic at Rochester, Minnesota, and found to be a substance containing 65 per cent of iodine and having marked physiological properties. Harington, in 1926, determined the structure of thyroxine, and in 1927, Harington and Barger reported the synthesis of the compound.

When Kendall was able to remove iodine from thyroxine and show that the resulting product would not stimulate development, the place of iodine among nutritionally essential mineral elements could no longer be questioned. The need for iodine in the formation of this thyroid hormone is now recognized as its major role in the human organism.

Various species of animals have been found to suffer from iodine deficiency; it was estimated in 1916 that about one million young pigs were lost annually in Wisconsin because of being born hairless and otherwise defective. In other western states (North and South Dakota, Washington, Minnesota) the pig industry was similarly

menaced. The mothers appeared normal, but the thyroid glands of hairless offspring were found to be abnormally large and abnormally low in iodine. A careful canvass of the whole situation led to the conclusion that iodine starvation of the fetus depressed the activity of the fetal thyroid and caused the remarkable arrest of development. When suitable amounts of iodine were administered to the mothers during the gestation period there was not only prevention of the hairless condition but also a marked improvement in the vitality of the young pigs.

Other farm animals, such as sheep, calves, colts, chickens, and dogs, have suffered extensively from goiter, and in all of these species administration of iodine has been as successful as with pigs.

As old as history itself is the incidence of goiter in the human race. Kimball remarks that the *Arthorva Veda*, an ancient Hindu collection of incantations dating from 2000 B.C., contains extensive forms of exorcisms for goiter. It was not until the middle of the nineteenth century, however, that the prevalence of goiter in European countries was made a matter of government investigation. For France alone, a commission appointed in 1864 reported ten years later 500,000 people suffering from goiter, and 120,000 cretins and cretinoid idiots. In all southern Europe the problem of goiter and cretinism has been of sufficient economic importance to justify national commissions for its investigation.

In the United States there is a wide goiter belt stretching along the Appalachian Mountains as far north as Vermont, westward through the basin of the Great Lakes to the state of Washington, and southward over the Rocky Mountain and Pacific states; but no attempt to prevent human goiter on a large scale seems to have been made previous to 1917. Then Marine and Kimball, reasoning that if goiter could be prevented in animals by administration of iodine, it should be preventable also in the human species, undertook to prove the possibility of such prevention in the public schools of Akron, Ohio, a large manufacturing town in the goiter belt. They secured the co-operation of the Superintendent of Schools, the Board of Education, and the County Medical Society, and in April 1917, began a systematic census of the thyroid glands of all the girls from the fifth to the twelfth grades of the elementary schools. The boys were not examined because of the relative infrequency of serious thyroid enlargement in boys. The results were as follows:

INCIDENCE OF GOITER IN SCHOOL GIRLS OF AKRON, OHIO,
IN 1917

<i>State of Thyroid Gland</i>	<i>Number of Girls</i>	<i>Per Cent of Total Number Examined</i>
Normal	1,688	43.2
Slightly enlarged	1,931	49.3
Moderately enlarged	246	6.3
Markedly enlarged	7	0.2
Toxic	39	1.0
Total number examined	3,911	100.0

As many of these girls as volunteered were given small doses of sodium iodide dissolved in drinking water in quantity to furnish from 3 to 5 milligrams of iodine twice weekly over a period of a month, and repeated twice yearly. In 1920, as a result of two and one-half years' observations, the investigators reported that of over 2,000 pupils taking the treatment only 5 developed thyroid enlargement, while of a similar number not treated nearly 500 showed enlargement during the same time.

Iodine and Goiter Prevention

This strikingly successful demonstration aroused much interest in goiter prevention both in other parts of this country and abroad. In the spring of 1918, Professor R. Klinger of Zurich, Switzerland, undertook to carry out similar treatment in three Swiss cantons, Saint Gallen, Berne, and Zurich, with school populations in which the incidence of goiter varied from 82 to 95 per cent. In 1922 a report of the Health Commission of the Canton of Saint Gallen gave the following statistics: incidence of goiter among all the school children of Saint Gallen, January 1919, 87.6 per cent; January 1922, 13.1 per cent. By 1929 there were nine cantons in which only iodized salt was used and in all but a few of the others it was consumed more or less freely. In the Canton of Appenzell the Swiss Goiter Commission reported that after five years there was a total disappearance of congenital goiter and of goiter among young school children, with a fall of 75 per cent in operations for relief of goiter in adults. There was also a decline in the number of stillbirths and infant deaths due to thyroid deficiency and an average increase of 100 grams in the birth weight.

In this country Michigan has been one of the foremost states in

establishing and maintaining a goiter prevention program. In 1928, after four years of educational work on the part of the State Medical Society and the State Board of Health, and continued effort on the part of the Wholesale Grocers' Association to bring about the sale of iodized salt exclusively, the school children were examined in certain districts to see what the effect of the policy had been. In every instance the decline in the incidence of goiter was striking. A part of the plan was a general resurvey in ten years and this was made in 1935, with the result that the percentage of goiter was reduced from 40 in 1924 to 8 in 1935. In Midland County, where the original survey had shown fully one-third of the children to have well-established goiters and practically every child to have some enlargement, the disease was almost completely stamped out, 90 per cent of the children being reported as normal. An interesting incident of the survey was the situation in the town of Calumet, where closing of the copper mines in 1932 had thrown two-thirds of the families upon relief. These families were given only plain bag salt. Furthermore, families who were buying their own groceries were many of them in such financial straits that they, too, bought bag salt because it was cheaper. Thus the use of iodized salt was discontinued through the next three years, with the result that the number of cases of goiter, which had been reduced to a very low figure, became as great as before 1924.²⁵

The prevention of goiter has thus been shown to be a nutritional problem. The body has a more or less definite requirement for iodine to meet daily losses and maintain such a reserve as is necessary for the production of sufficient amounts of thyroxine for health and growth. The level of iodide in salt may vary from 1 part of sodium or potassium iodide in 5,000 to 1 part in 200,000 parts of salt. "The added iodide is not to be regarded as a drug but rather as restoring the table salt to something like its natural composition—the ordinary table salt of today being the product either of the selection of exceptionally pure sodium chloride mineral (halite) or of an artificial refining process, and being thus in a sense denatured."²⁶

²⁵ For further reports see Oleson, R. *Endemic Goiter*, Public Health Bulletin No. 192, U. S. Public Health Service (1929); and Kimball, O. P. "Prevention of Goiter in Michigan and Ohio." *Journal of the American Medical Association*, Vol. 108, page 860 (1937).

²⁶ Sherman, H. C. *Chemistry of Food and Nutrition*, 8th edition, page 326. The Macmillan Co. (1952).

Although, with the continued use of iodized salt, the incidence of endemic goiter in the United States has decreased and is no longer considered a major problem, this is not true among other populations in the world. In 1951, Dr. F. W. Clements, Chief of the Nutrition Section of the World Health Organization, pointed out that endemic goiter was probably the world's most prevalent deficiency disease (see Figs. 51 and 52). Goiter occurs frequently in Central America, Austria, and in Yugoslavia. A reduced incidence of goiter has been found where the iodine content of the water is high, but it must be kept in mind that it is the nature of the food supply that determines the major intake of iodine.

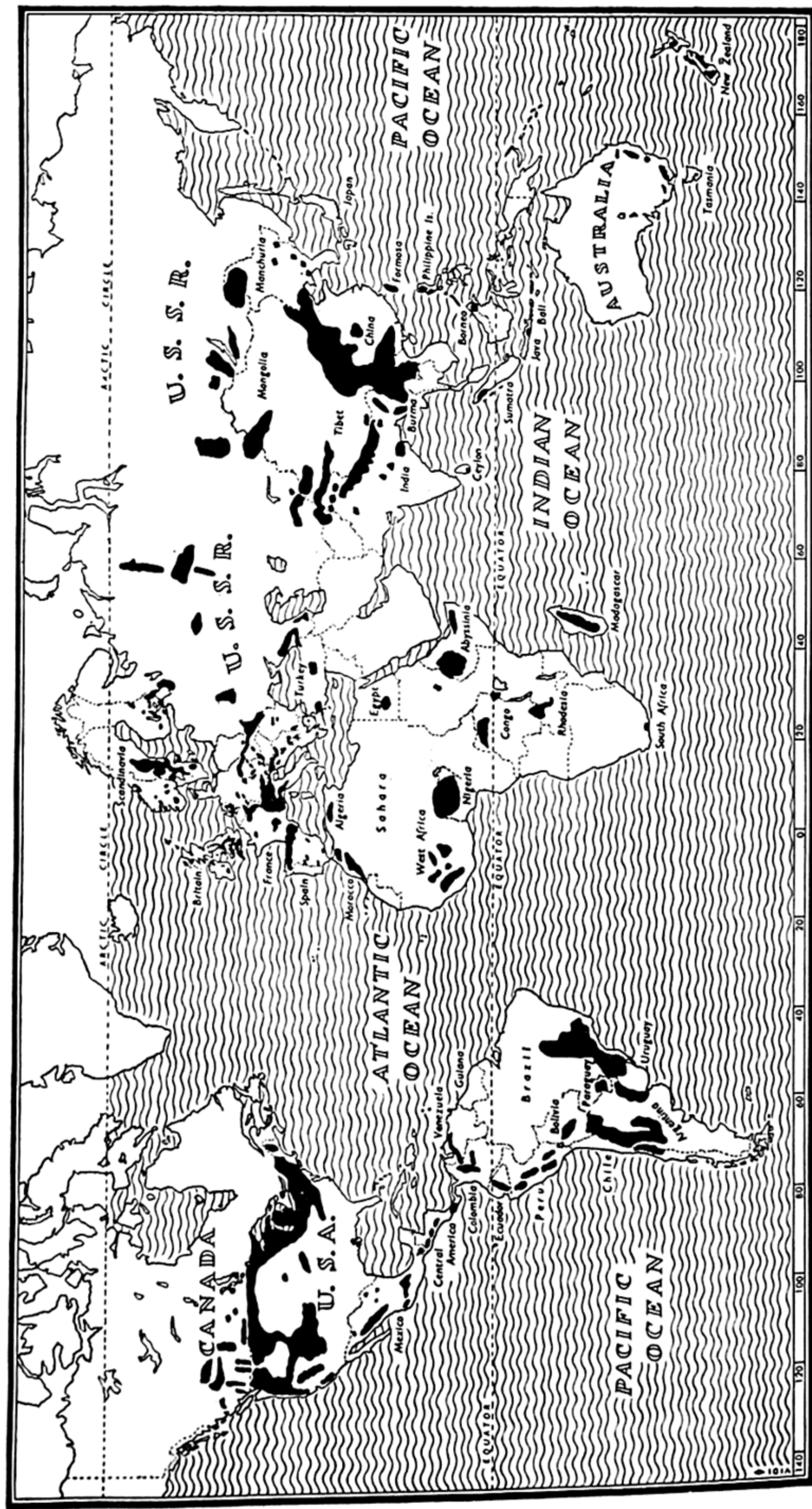
The Iodine Requirement

Curtis and Fertman, in 1951, estimated the magnitude of the requirement for iodine to be of the order of 1 to 2 micrograms (0.001 to 0.002 milligram) per kilogram of body weight per day. A slightly higher estimate has been made by the Food and Nutrition Board of the National Research Council. In 1953, the Council recommended as a desirable daily intake of iodine about 0.002 to 0.004 milligram for each kilogram of body weight, or a total of 0.15 to 0.30 milligram daily for adults. They state that this can easily be met by the regular use of iodized salt which is especially important during early adolescence and pregnancy. However, Darby²⁷ points out that it is not safe to assume that the world's goiter problem will be solved by education in the use of iodized salt. In many areas of the world where crude salt is used instead of the refined product the stability of the iodine presents a problem. The process of cooking may affect the stability and retention of the iodine. Also, it has been pointed out by Osmond and Clements²⁸ in Australia that 10 per cent of the children ten years of age in Canberra do not use salt at the table and 30 to 35 per cent of the children three to four years of age do not use salt at all.

Darby calls attention, however, to the effectiveness of the administration of iodine either in drinking water or as iodized salt in the prevention and treatment of endemic goiter over a long period of

²⁷ *Symposium on Nutrition*, edited by Herriott, page 238. The Johns Hopkins Press (1953).

²⁸ Osmond, A., and Clements, F. W. "Goiter Studies. III. The Iodine Prophylaxis of Endemic Goiter." *Medical Journal, Australia*, Vol. 1, page 753 (1948).



(Courtesy of the Chilean Iodine Educational Bureau, London, England)

Fig. 51. Map Showing the Goiter Areas of the World

years and cautions that its importance must be constantly kept in mind as a public health measure in order to insure the continuation of the practice.



(Courtesy of INCAP Photo by Gey)

Fig. 52. A Group of Women Showing Endemic Goiter in a Goitrous Region of Guatemala

This photograph was taken in the village of Parramos in the Guatemalan Highlands. Dr. N. S. Scrimshaw, Director of the Institute of Nutrition of Central America and Panama, reports that women with these degrees of goiter are exceedingly common.

Iodine in Food and Water

Our knowledge of the iodine content of food materials is as yet limited, owing largely to the technical difficulties involved in determining such minute amounts of iodine as are found in common articles of diet. A curious instance of a single item of the diet preventing goiter is found in Pemberton Valley in British Columbia. It is said that in former years every white baby born in this valley had a goiter, and nine-tenths of all the colts and the calves died. Yet in a village of Indians in this valley there was never any goiter, although Indians living in Minnesota, Michigan, and Wisconsin are as frequent victims as the white inhabitants. Keith, who has studied the Pemberton Valley, comments thus on the situation: "Whilst considering the lack of goiter among these Indians I would like to draw

attention to the fact that they eat a great deal of salmon . . . and annually cure thousands for winter use. Their pigs also eat the dead salmon washed ashore on the gravel banks of the stream. It is quite probable that the Indians and their pigs get enough iodine from the salmon to give their thyroids the necessary quantum of this element."²⁹

Von Fellenberg, employed by the Swiss Goiter Commission to study the distribution of iodine in nature, found that foods from a goitrous territory contained less iodine than the same kinds from nongoitrous regions. He found milk (particularly milk fat), leafy vegetables, and fruits to be higher in iodine than other common types of food. Comparison of foods from goitrous and nongoitrous regions in this country have shown the same trends, as the figures given below indicate.

DIFFERENCES IN IODINE CONTENT OF FOODS FROM GOITROUS
AND NONGOITROUS REGIONS IN PARTS PER BILLION
OF DRY MATTER

<i>Food</i>	<i>Goitrous Regions</i>	<i>Nongoitrous Regions</i>
Milk	265-322	572
Potatoes	85	226
Carrots	2	170-507
Wheat	1-6	4-9
Oats	10	23-175

Sea foods are all rich sources of iodine. Salmon, whether canned or fresh, ranges from 570-2,200 parts per billion of dry matter; oysters, 1,800-3,500 parts; codfish, 5,350 parts; and cod liver oil, from 3,000 to 13,000 parts.³⁰

From the earliest times it was popularly believed that the incidence of goiter was related to the water supply. Thus only did it seem possible to explain many instances of the close proximity of a goitrous to a nongoitrous region. Chemical evidence that this was not superstition or due entirely to other causes was afforded by a study of goiter by the Department of Health of the State of Michigan in 1924. "It was found that localities separated only a few miles varied in

²⁹ Keith, W. D. "Endemic Goiter." *Canadian Medical Association Journal*, Vol. 14, page 284 (1924).

³⁰ For other foods consult Sherman, H. C. *Chemistry of Food and Nutrition*, 8th edition. The Macmillan Co. (1952) and Coulson, E. J. *The Iodine Content of Some American Fishery Products*. Investigational Report No. 25, Bureau of Fisheries, U. S. Department of Commerce (1935).

percentage of thyroid enlargements in native children from 10 to 100 per cent. One notable instance of this where there were sufficient children for a satisfactory random sample was in the difference in percentage of thyroid enlargement between Mount Clemens, which had 26 per cent, and Romeo, 12 miles distant, which had 75 per cent. Mount Clemens has an iodine content in the city water supply of approximately 25 parts per billion, while Romeo water does not contain a trace of iodine in 50 liters."³¹

However, it is not the simple drinking of water which prevents goiter; even in the case of waters containing 10 parts per billion of iodine, 10 quarts of water would have to be drunk to get 0.1 of a milligram of iodine, the dose recommended for a school child. The iodine in the water is to be regarded as indicative of the iodine in the soils which come in contact with the water. Plants growing in the soils are the agency by which it is concentrated for human use. In regions which are nongoitrous, it seems highly probable that most persons may secure sufficient iodine by a liberal inclusion of milk and green vegetables in their diet.

Section 5. FLUORINE

In 1916, McKay³² reported that the factor causing mottled enamel of the teeth was due to something present in the water supply during the period of tooth development. He came to this conclusion after an examination of 6,873 individuals in 26 communities or rural districts. At that time the methods for water analysis were of no help in finding the unknown element which was likely to cause this mottled condition of the teeth. It was not until 15 years later, in 1931, that three separate laboratories³³ published evidence showing

³¹ Olin, R. M. "Iodine Deficiency and Prevalence of Simple Goiter in Michigan." *Journal of the American Medical Association*, Vol. 82, page 1331 (1924).

³² McKay, F. S. (in collaboration with Black, G. V.). "An Investigation of Mottled Teeth." *Dental Cosmos*, Vol. 58, pages 627-644, 781-792, 894-904 (1916).

³³ Smith, M. C., Lantz, E. M., and Smith, H. V. *The Cause of Mottled Enamel, A Defect of Human Teeth*. University of Arizona Experiment Station Technical Bulletin No. 32 (1931); Churchill, H. V. "Occurrence of Fluorides in Some Waters of the United States." *Journal of Industrial and Engineering Chemistry*, Vol. 23, page 996 (1931); Velu, H. "Dystrophie Dentaire des Mammifères des Zones Phosphatées (Darmous) et Fluorose Chromique." *Compt. Rend. Soc. de Biol.*, Vol. 108, page 750 (1931).

that high levels of fluorides in the water were evidently responsible for the dull, chalky, white blotches and frequently unglazed appearance on the surface of the teeth, known as mottled enamel. As this condition progressed the teeth became stained and developed a characteristic brown color. Eventually, the enamel became pitted.

Extensive studies followed to ascertain the level of fluorides in drinking water in many parts of the United States, the findings of which helped to establish pertinent facts. Drinking water having a fluoride content of 2.0 to 2.5 p.p.m. (parts per million) and above was found to result in fluorosis of an extremely disfiguring degree and the incidence and severity of the fluorosis increased as the levels approached 10 to 20 p.p.m. In localities where these very high levels were found almost all of the natives had severe dental fluorosis. When the fluoride content of the water was as low as 1 p.p.m., a low incidence of dental caries was found. A high incidence of dental caries was found among children growing up in communities where the fluorine in the drinking water was less than 0.5 p.p.m. This pointed out that too little fluorine tended to cause dental caries, a little prevented dental caries, while too much caused the unsightly mottled enamel.

In Colorado Springs, Colorado, drinking water, which had been obtained from the same source for 75 years, was found to have a natural fluorine content of 2.5 p.p.m. The teeth of 400 individuals, ten years of age and over, who had lived continually in Colorado Springs, were examined. In the older group of inhabitants, that is, those between forty and forty-four years of age, an average of 0.61 tooth per person was found to be decayed or filled in contrast to an average of 10.2 teeth per person in the United States as a whole. No harmful symptoms which could be traced to the higher fluorine content of the water were noted.

Under normal conditions bones and teeth have been found to contain some fluoride and where the intake of fluoride is high, retention of fluoride in the body is increased, but when the amount ingested is low, little is retained. The fluorine content of the enamel of sound teeth has been reported to be higher than that of the enamel of carious teeth. In mottled teeth the enamel was found to be two to three times as high in fluorine as in sound teeth.

These findings paved the way for many more surveys of the fluorine content of water in different locations and the effects on

teeth, the results of which established the fact that fluorine in drinking water at a level of 1 p.p.m. was the most desirable level for the control of dental caries.

During 1945 and 1946, long-term studies of the artificial fluoridation of drinking water were started in several experimental communities. Grand Rapids, Michigan, the first city in the world to initiate such a program, started it in January 1945. The city of Aurora, Illinois, having a water supply with a natural fluoride content of 1.2 p.p.m., was used for comparison. Periodic examinations of the teeth of the children living continuously in Grand Rapids were conducted. Ten years of continuous fluoridation of the water supply showed a reduction in the decay of permanent teeth of from 76 per cent in six-year-olds to 29 per cent in the sixteen-year-old group. In 1945, Aurora had about two-thirds less tooth decay than Grand Rapids. At the end of the ten-year period the incidence of tooth decay in the two cities was found to be approximately the same.

In April 1945, another convincing study was started in Newburgh, New York, and the city of Kingston, just 38 miles away. In both cities the drinking water had an extremely low fluorine content. The water of the city of Newburgh was treated with fluoride to bring the content of fluorine to the level of 1 p.p.m. while the water of the city of Kingston remained untreated. Periodic examination of the school children has been continued for ten years. On the tenth anniversary of the initiation of the program, Dr. David B. Ast, Director of Dental Health, New York State Department of Health, reported an average of 60 per cent reduction in the decayed, missing, or filled teeth (d.m.f.) among the children of Newburgh as compared with those in the city of Kingston where the water was not fluoridated. The six- and seven-year-old children in Newburgh who had always had fluoridated water showed an improvement in dental health of 68 to 75 per cent. No adverse effects of the fluorine were found among the children participating in the study.

Other factors such as a deficient diet and hereditary tendencies also play an important role in the prevention of tooth decay and must not be overlooked, but the convincing evidence of the beneficial effects of established levels of fluorides in drinking water now available from these carefully controlled studies should alleviate any fear of disastrous effects from the fluoridation of drinking water.

In September 1954 it was reported at a meeting of the American

Dental Association that more than 1,000 communities were then drinking water fluoridated artificially. In addition about ten million people in the United States were fortunate enough to have drinking water which had a natural fluoride content of the optimum level of 1.0 to 1.5 p.p.m. Dr. H. T. Dean,³⁴ formerly Dental Director of the National Institute of Dental Research, National Institutes of Health, Public Health Service, Bethesda, Maryland, in 1953 reported on fluoridation as follows, "A scientist can only base his opinion on known available observed facts and these are that there are no known untoward effects developing in the millions of persons using water naturally containing fluoride at about 1.0 parts per million of fluorine. Such evidence cannot be ignored, nor can the fact be disregarded that all the studies thus far conducted to explore these specific points have supported the safety of fluoridation." Dean also points out the need for continued research.

Section 6. OTHER TRACE ELEMENTS

Manganese was recognized as an essential nutrient through experimental work with rats. On a diet of cow's milk supplemented with iron and copper, rats were found to make better growth when manganese was added. Without the manganese there was a delay in sexual maturity and when the females finally bore young, these were either dead or so weak that most of them did not survive more than a few days. Their bodies contained less than half as much manganese as those from mothers on a similar ration with added manganese. On a strictly manganese-free diet male rats became completely sterile because of degeneration of their testes and female rats were unable to suckle their young. Addition of manganese to their diet resulted in normal development through several generations.

In chickens a manganese deficiency results in a condition known as perosis (slipped tendon). Also, a low hatchability of eggs laid by hens whose diets were deficient in manganese has been reported. The embryos which developed had shortened leg and wing bones and distorted beaks. Poultry rations commonly contain a manganese salt

³⁴ Dean, H. T. "Some Reflections on the Epidemiology of Fluorine and Dental Health." *American Journal of Public Health*, Vol. 43, Part I, page 708 (June 1953).

which serves as a protective measure. Manganese has also been found to be an essential nutrient for swine.

The requirement of manganese in animal nutrition is very low, only about $\frac{1}{10}$ that of copper and $\frac{1}{100}$ that of iron. Certain combinations of other mineral elements may either increase the requirement or decrease its availability. Manganese is present in plant tissues generally, as well as in those of the animals which eat the plants, so that on an ordinary mixed diet there seems no likelihood of a deficiency of this element.³⁵ Of the manganese present in animal tissues, the highest concentration is in the liver.

Zinc is recognized today as an essential trace element in the nutrition of man. It is known to be present in a number of enzymes, for example, carbonic anhydrase in both the red and the white corpuscles of the blood; the pancreatic enzyme, carboxypeptidase; and others. It has been found to be interrelated with the metabolism of copper and molybdenum.

There is little likelihood of any deficiency occurring in human or animal nutrition on an ordinary mixed diet since zinc is so widely distributed in nature. Milk contains so much zinc that it cannot be used satisfactorily as a diet for the production of a zinc deficiency in laboratory animals.

In patients suffering from pernicious anemia, an elevation of the zinc concentration in the blood has been noted as well as an elevation of the activity of the enzyme, carbonic anhydrase.

Molybdenum was first recognized as an essential nutrient in 1953 through work on rats which established the fact that molybdenum is required to maintain normal levels of the intestinal enzyme, xanthine oxidase. The active factor was later isolated from soy flour and from liver, and found to be a salt of molybdenum.

Apparently most diets contain enough molybdenum to supply the amount needed for the production of xanthine oxidase in the liver. It has been reported that 0.2 to 0.3 microgram of molybdenum per rat would be adequate to produce a saturation level of xanthine oxidase. Molybdenum is associated with iron and the vitamin, riboflavin, in milk xanthine oxidase.

Molybdenum toxicity has been reported in ruminants under nat-

³⁵ For manganese in foods see Taylor and MacLeod. *Rose's Laboratory Handbook for Dietetics*, 5th edition, page 265. The Macmillan Co. (1949).

ural grazing conditions and has been found to interfere with copper metabolism. Toxic effects have also been noted in rats, guinea pigs, and rabbits. The condition can be alleviated by giving copper.

Foods considered as good sources of molybdenum include legumes, cereal grains, some dark green leafy vegetables, and animal organs (liver, kidney, and spleen). To be considered a good source a food should contain 0.6 parts of molybdenum per million parts of food. Fruits, berries, and most root or stem vegetables have been found to be relatively poor sources, having less than one-tenth part per million.

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Vitamin A

Discovery

Forty years ago the word vitamin was just coming into use. Today it is applied to those substances which occur in minute quantities in food and yet produce profound and specific physiological effects. They have been likened to the ignition spark of the automobile; they are, perhaps, more like the various hormones furnished to the body by the glands of internal secretion, such as thyroxine, insulin, cortisone, parathormone, etc., each circulating in the blood in exceedingly small amount, but nevertheless powerful in its control of some function indispensable for life, health, and growth. The vitamins which we recognize today as essential in human nutrition are for the most part formed by green plants, and from them transferred to the bodies of animals.

The first experimental evidence that animals could not exist on mixtures of purified proteins, fats, carbohydrates, and mineral salts came from the laboratory of Bunge at the University of Basel, Switzerland. In 1884 Lunin, one of his pupils, fed mice an artificial mixture of all the components of milk then known, but the animals failed to survive and he concluded his report thus: "A natural food such as milk must therefore contain besides these known principal ingredients small quantities of unknown substances essential to life." Bunge himself thought the real cause of the nutritional failure was some change in the form of the mineral elements which rendered them incapable of utilization and although another pupil, Socin, seven years later also became convinced that milk and egg yolk contained unknown substances of special significance for life and

growth, no systematic search for them was instituted in Bunge's laboratory.

In other parts of the world from time to time men found human diseases which could be cured by changes in diet, and laboratory workers sought animals in which similar diseases could be induced and then cured by the same foods which had proven efficacious for mankind.

Babcock at the University of Wisconsin determined to test rations derived from different plant sources to see whether there might be any difference in their nutritive value. With the cooperation at first of Hart and Humphrey and later of Steenbock and McCollum, an experiment was conducted on groups of young heifers, one group being fed a wheat plant ration (wheat straw, wheat gluten, and entire wheat grain); another a yellow corn plant ration; a third an oat plant ration; and a fourth a ration drawn from all three plant sources. For the first year of the experiment there was little to distinguish one group from another, but gradually the corn-fed group grew smoother in the coat and fuller in the barrel, while the wheat-fed group became rough of coat, gaunt and thin, and small of girth. The groups on the oat plant ration and the mixed ration stood intermediate between those on the corn and the wheat.

One of the first persons to appreciate the full significance of adding minute quantities of unknown substances present in natural food appears to have been Hopkins of Cambridge University. Although he did not venture to print the results of his own experiments until 1912, as early as 1906 he sounded the modern note: "No animal can live upon a mixture of pure protein, fat and carbohydrate, and even when the necessary inorganic material is carefully supplied, the animal still cannot flourish."¹

Hopkins fed young rats a diet of casein, lard, starch, cane sugar, and mineral salts obtained by mixing equal parts of ash of oats and dog biscuit. When these substances were highly purified, growth was arrested and decline and death speedily ensued, even though the food intake appeared sufficient. When to the purified ration were added only 2 or 3 cubic centimeters of milk daily—less than one-

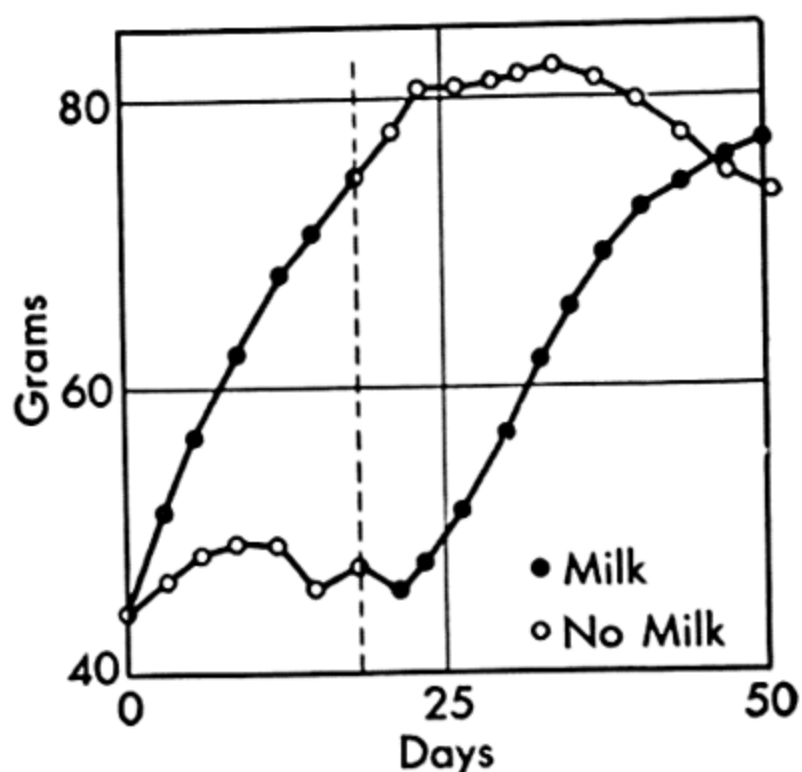
¹ Hopkins, F. Gowland. "Analyst and the Medical Man." *Analyst*, Vol. 31, page 385 (1906).

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third of a teaspoon—growth was promptly resumed, as shown in Fig. 53.

About the time that Hopkins was beginning this work, Osborne and Mendel in New Haven were initiating an investigation of the influence which proteins unlike in their chemical make-up might have upon nutritive processes. These investigators found difficulties in using highly purified rations and before long (1911) devised a preparation of milk freed of its casein, albumin, and fat, which they called "protein-free milk." By adding this to mixtures of pure starch, sugar, and fat along with any pure protein to be investigated, they were able to keep white rats alive through longer periods of time than had ever before been possible, but they found that beyond periods of about 100 days little or no increase in body weight was induced, although the animals remained for some time in good condition. When whole milk powder was substituted for the casein and protein-free milk, they were able to bring their animals through two generations. They concluded that the essential difference between the two diets lay in the milk fat. When, accordingly, butter was substituted for lard in the protein-free milk food, growth was promptly resumed and adult size attained.

While these experiments were going on in New Haven, progress in growth control was also being made in Wisconsin. McCollum and Davis, meeting similar difficulties in promoting growth on purified rations, found that resumption of growth occurred promptly when an ether extract of egg or butter was added. Thus two different



(Courtesy of Dr. F. G. Hopkins)

Fig. 53. The Effect upon the Growth of Young Rats of Adding a Small Amount of a Food Containing Vitamins to a Diet of Purified Food Materials

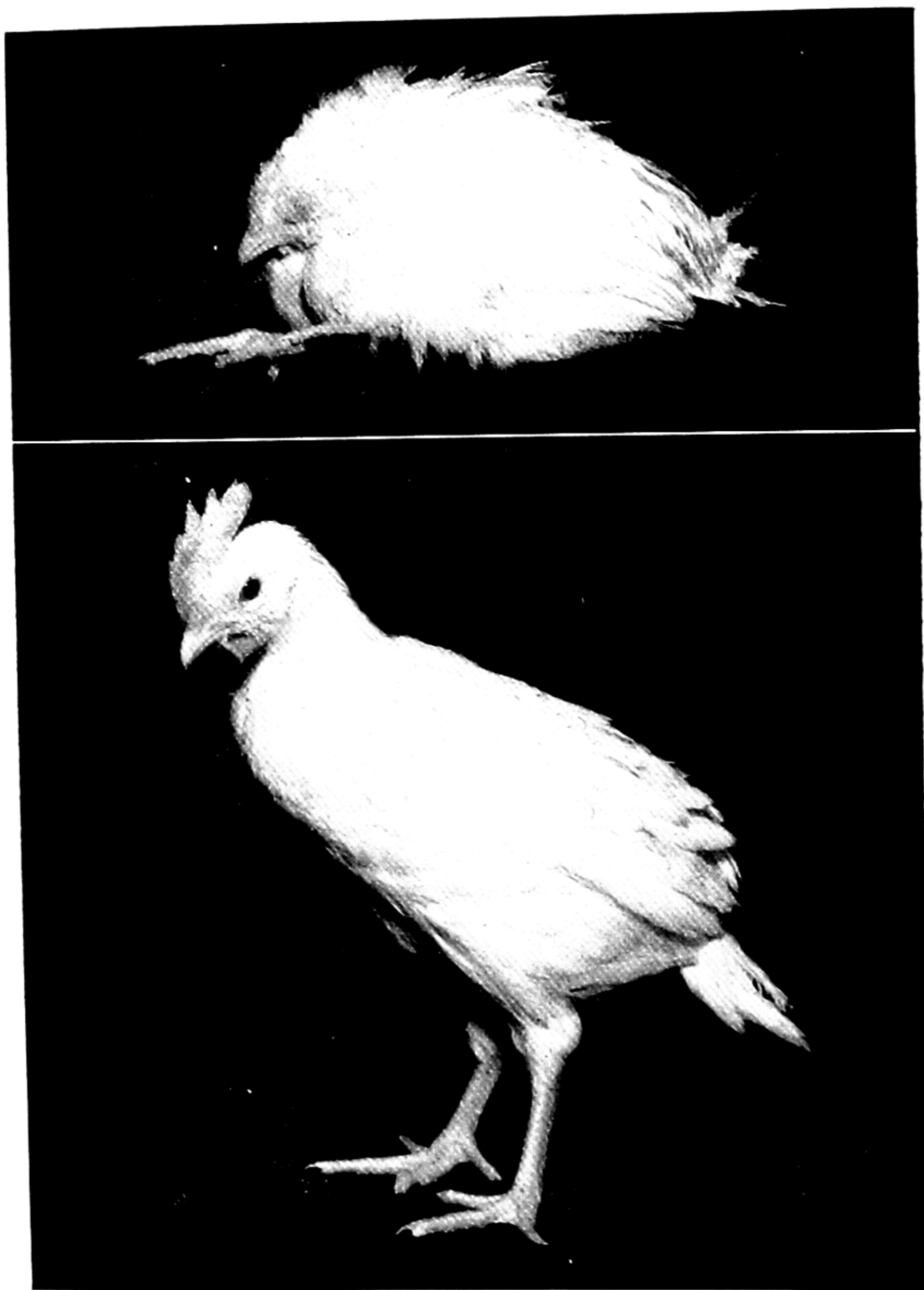
The lower curve (up to the eighteenth day, represented by the dotted line) shows the average weight of eight rats upon the purified food. The upper curve shows the average weight of eight similar rats taking 3 ml. of milk daily. On the eighteenth day, the milk was transferred from one set to the other.

laboratories, attacking the problem from quite different angles, simultaneously discovered that there is something in butter fat and egg yolk not found in lard and common vegetable fats which is essential for growth and which cannot be manufactured by the animal organism. This substance is now known as vitamin A.

The search for vitamin A in foods went forward by leaps and bounds after 1913. Not only fish liver oils, eggs, and butter, but also green leaves and yellow parts of plants proved to be excellent sources. Carrots and sweet potatoes were found to be rich sources while white turnips and potatoes furnished practically none. In 1919 Steenbock at the University of Wisconsin, finding that yellow corn could be used as the only source of vitamin A in the diet of young rats with excellent results, while white corn was very deficient, called attention to the remarkable coincidence in the occurrence of the yellow coloring matter of plants and the success in nutrition when they were used to furnish vitamin A. He extracted some of the pigment of carrots, known as carotene, crystallized it, and found that the crystals had vitamin A activity.

In many parts of the world, interest in the relationship between carotene and vitamin A became very keen. In Paris, in 1932, a sample of carotene made from spinach forty years previously and kept in a sealed tube as a museum specimen was brought forth and a portion fed to vitamin A-deficient rats, with the same success that had attended Steenbock's experiments. At the University of Wisconsin, Hart and some of his co-workers using chicks, which also require vitamin A, compared the effect of two kinds of plant coloring matter in spinach, one being carotene and the other a related substance known as xanthophyll. All the chicks grew well for about four weeks, then those on the vitamin A-free diet developed severe symptoms of vitamin A deficiency. Growth ceased, feathers became ruffled, a staggering gait developed, then the birds finally appeared drowsy and lay over on one side. In a few days they were dead. Those given xanthophyll were no better off, but those given as little as 0.03 milligram of carotene per day grew at a normal rate and remained in excellent health. The difference is shown in Fig 54.

Thus evidence accumulated that carotene is the substance out of which the body can manufacture vitamin A and consequently it is often referred to as provitamin A. Preparation of carotene crystals on a commercial scale has now made them available at low cost.

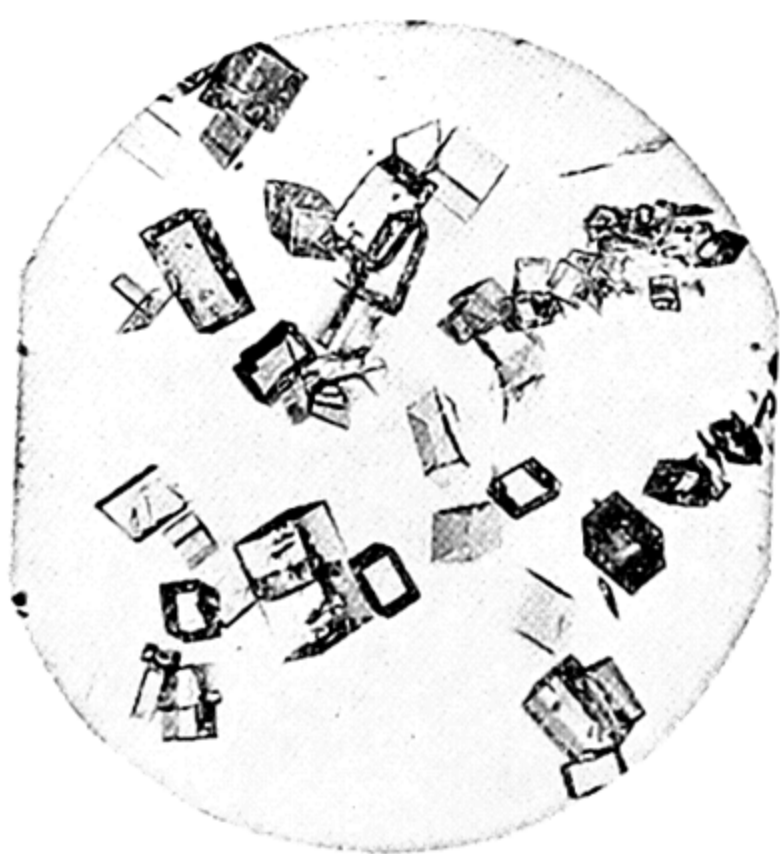


(Courtesy of Professor E. B. Hart)

Fig. 54. The lower chick received 0.03 mg. of carotene daily in addition to a basal diet adequate in all respects except vitamin A. It exhibited no vitamin A deficiency and weighed 320 grams at five weeks. The upper chick received 0.25 mg. of xanthophyll daily in addition to the basal diet. It developed symptoms characteristic of vitamin A deficiency and weighed only 160 grams at five weeks.

There are four substances differing only slightly in chemical constitution, alpha-, beta-, and gamma-carotene, and cryptoxanthin, all of which yield vitamin A but beta-carotene twice as much as the others. Our plant foods very generally contain no vitamin A as such, but owe their vitamin A values to their content of provitamin A, while foods of animal origin commonly contain both the vitamin and one or more precursors of it. We therefore speak of the vitamin A values of foods rather than their vitamin A content. In 1950 three groups of investigators reported the synthesis of beta-carotene.

In 1934 the International Unit of vitamin A (and also the United States Pharmacopeia unit) was set at 0.6 microgram of pure beta-carotene, and this is still used for the measurement of carotenes. In 1949 it was also fixed at 0.344 micrograms of vitamin A acetate by the World Health Organization (Fig. 55).



A



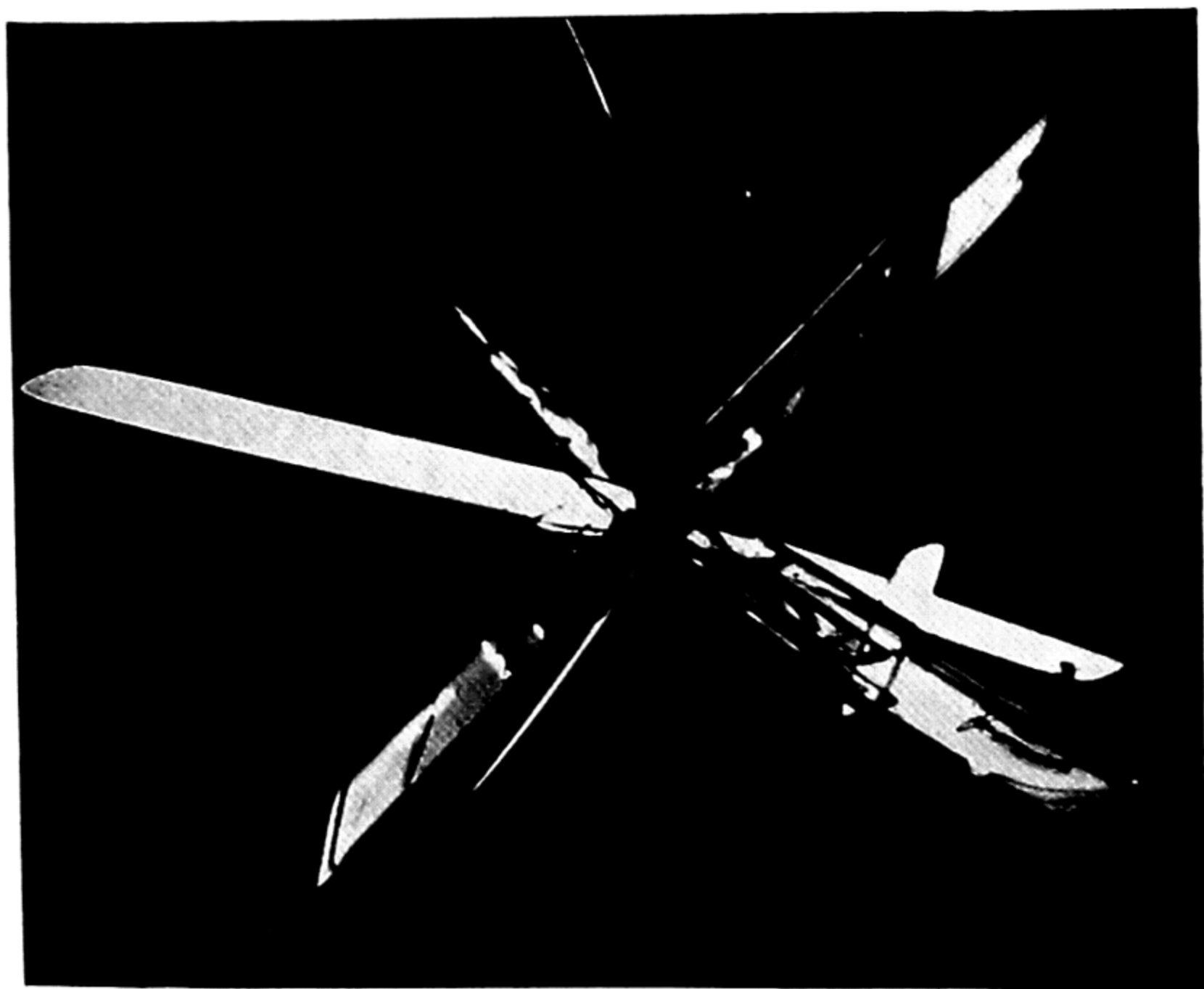
B

(Courtesy of Hoffmann-La Roche, Inc.)

Fig. 55. Crystals of Vitamin A Acetate (A) and of Beta-Carotene (B)

When cod liver oil was discovered to be a rich source of vitamin A, other fish oils were investigated and some of them were also found to be rich in this vitamin. Among them, halibut liver oil proved an easily available source of material from which to isolate the vitamin in pure form. The first step was the preparation of a vitamin A concentrate. This was a slightly yellow, oily substance giving certain well-established tests for vitamin A, and from it Karrer at the University of Zurich, Switzerland, was able to determine the chemical

constitution in 1933. Crystallization of the vitamin and removal of the last trace of impurity was accomplished in 1934 by Holmes at Oberlin College. He reported a product almost 100 per cent pure having as high as 14,000 times the potency of standard cod liver oil, but it took nearly three more years of effort to achieve complete success. In the latter part of 1936 he was able to show the first pure, pale yellow, needle-like crystals of vitamin A,² prepared from the liver oil of Atlantic Ocean mackerel, and a little later obtained others from a Japanese fish, *Stereolepis ishingii*. Samples of these crystals were sent to three other laboratories where their biological activity was tested and reported to be about 3,000,000 International Units per gram. Synthetic vitamin A is now available, methods for synthesizing it having been developed in a number of laboratories (Fig. 56).



(Courtesy of Merck & Co., Inc.)

Fig. 56. Crystalline Vitamin A Highly Magnified

² Holmes, H. N., and Corbet, R. "A Crystalline Vitamin A Concentrate." *Science*, Vol. 35, page 103 (1937).

It has been established that the vitamin A occurring in the livers of salt water fish is not identical with that found in the livers of fresh water fish. The two forms are designated as vitamin A₁ and vitamin A₂ respectively. The name axerophthol has been accepted for vitamin A₁. They are, however, so much alike functionally that they are commonly referred to collectively as vitamin A.

The Promotion of Growth

As already stated, vitamin A was discovered through the failure of rats to grow for more than 70 to 120 days on rations adequate in protein, mineral salts, and the vitamin B complex, and their prompt resumption of growth when butter fat or an ether extract of egg yolk was added to the ration. At first there was much irregularity in the time required by different animals to show signs of vitamin A deficiency, but it was soon realized that if the animals placed upon the vitamin A-free diet had been previously fed one rich in it, they continued to grow for a much longer time than those whose former diet had been good in all other respects but low in vitamin A. The upper rat in Fig. 57 shows the characteristic effects of a diet lacking



Fig. 57. These Two Rats Are the Same Age. The Lower One Had an Adequate Diet, the Upper One a Diet Lacking Vitamin A

Vitamin A

vitamin A. Typical growth curves for such animals, weaned at the age of four weeks from a mother on an adequate diet, and placed on a diet entirely free from vitamin A (Fig. 58), indicate how growth continues until the vitamin A reserves of the body are exhausted. If the vitamin is not added to the diet when growth ceases, symptoms of deficiency soon become marked and death ensues, but if the vitamin is supplied growth is promptly resumed.

Reproduction and Lactation

After the vitamin B complex had been discovered and attempts were being made to rear animals on diets of purified casein, lard, cornstarch, and mineral salts to which a daily portion of yeast was added, it was found that, while the young animals grew for some time at a good rate, they matured late and were frequently sterile or else bore offspring so feeble that they soon died. This type of diet contained little if any vitamin A. Upon the discovery of the existence of vitamin A and the substitution of butter fat for part of the lard, it became possible not only to secure growth to full maturity but also to obtain a second generation of animals and bring them, too, to successful reproduction.

In the classic Wisconsin experiment with rations derived from a single plant source, the most unexpected result was the difference in the reproductive capacity of the cattle on the different diets. Normal young could not be produced on the wheat plant ration; the estrus cycle was delayed and in some individuals never appeared. On the corn ration the reproduction cycle was complete, and when yellow corn grain was substituted for the wheat grain in the wheat plant ration, reproduction again become normal. It was not then known that yellow corn contained vitamin A. In 1924, the Wisconsin experimenters improved the wheat plant ration, correcting its deficiencies

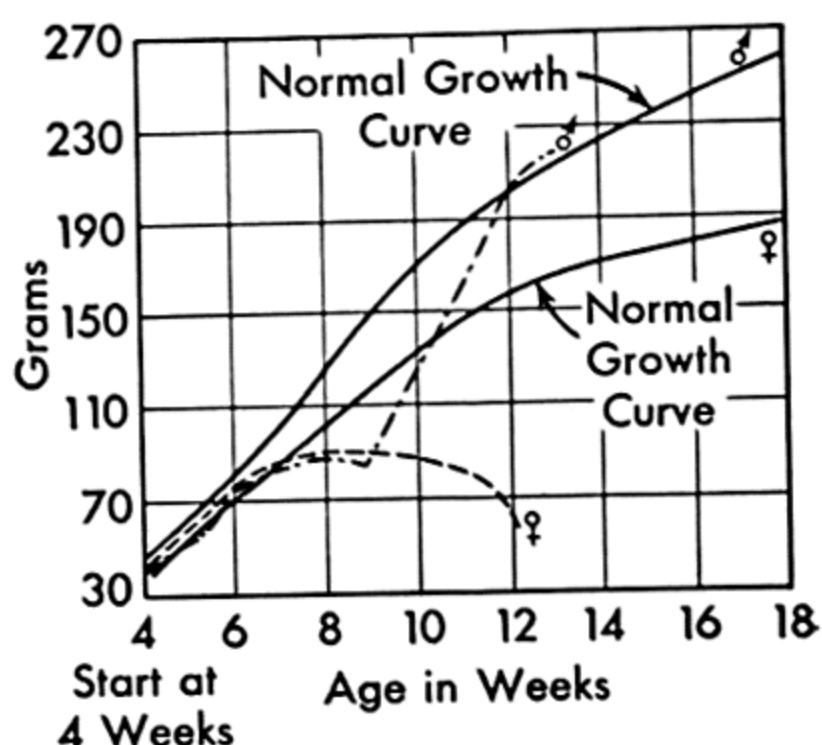
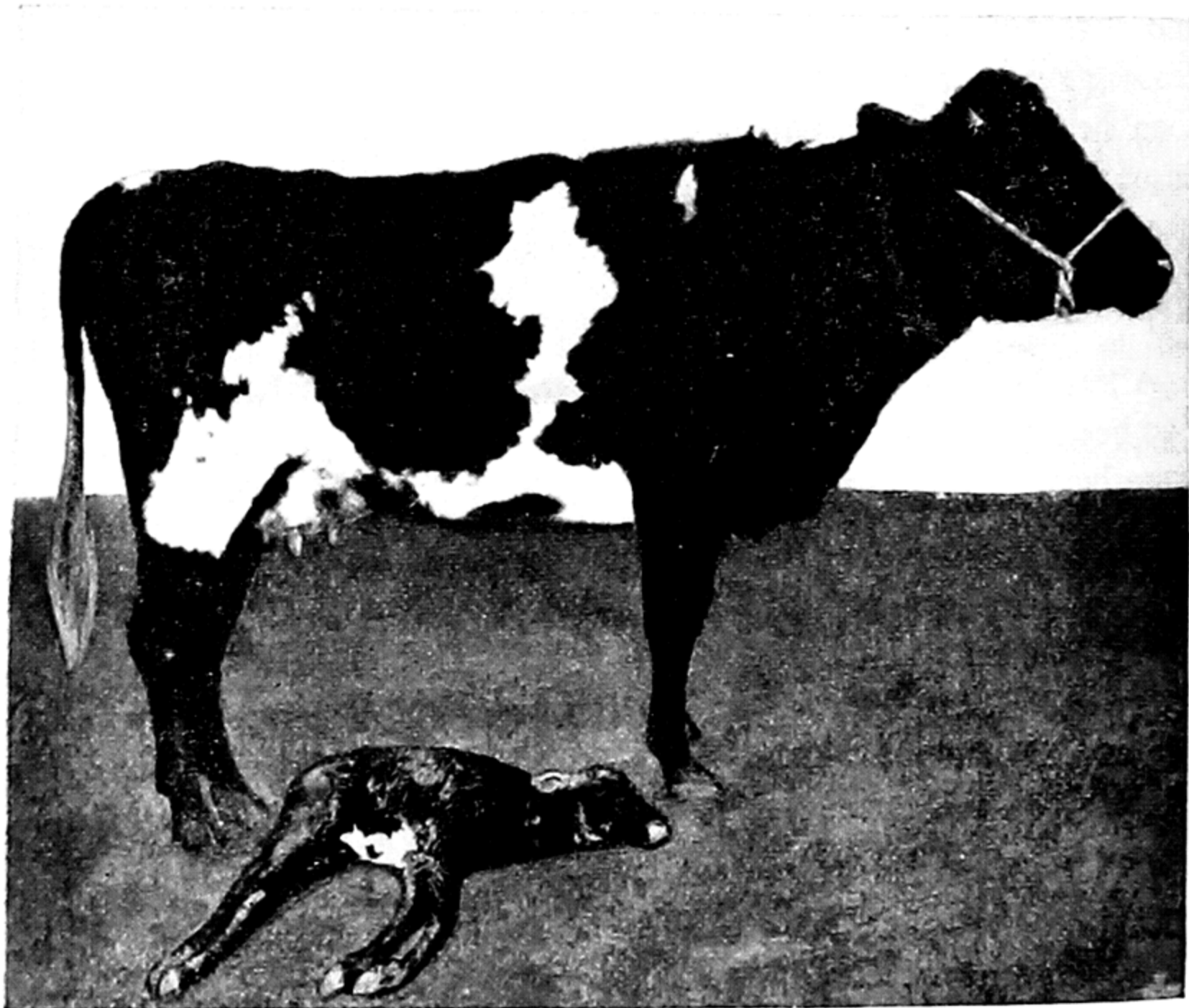


Fig. 58. Growth of rats on a vitamin A free diet compared with that of rats of the same age on a normal diet. When vitamin A was added to the diet of the male after five weeks deprivation, it doubled its weight in two and a half weeks. The female, given no vitamin A, continued to lose weight and died.

by adding to the original ration of wheat meal, wheat gluten, and wheat straw, mineral salts and 2 per cent of raw cod liver oil. No more beautiful demonstration of the triumph of dietary knowledge can be found than in the contrast between the wheat-fed cow and calf of 1907 and those of 1924 (Figs. 59 and 60).



*(From Research Bulletin 17, University of Wisconsin
Agricultural Experiment Station)*

Fig. 59. In 1907, feeding a ration made from wheat straw, wheat meal, wheat gluten, and common salt, resulted in nutritional disaster. The cow was shaggy-coated, slow and sleepy in movement, and had a tendency to drag her hind feet. The calf was born prematurely and died.

The interference with reproduction caused by lack of vitamin A is unlike that brought on by any other dietary deficiency, and is cured by raising the amount of vitamin A to a higher level. This has been demonstrated by Sherman and F. L. MacLeod, who took two groups of rats from mothers on an adequate diet and fed them diets alike in all respects other than vitamin A content. One diet was low and the other high in vitamin A content. The diet with the lesser

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amount of vitamin A proved sufficient for normal growth up to nearly average adult size, but not for successful reproduction. The animals receiving the more liberal allowance of vitamin A grew to fully average adult size and reproduced successfully.

The vitamin A content of milk is influenced to some extent by the



(Courtesy of Drs. E. B. Hart and H. Steenbock)

Fig. 60. In 1924, when the ration of 1907 was supplemented with bone meal 2 per cent, common salt 1 per cent, and raw cod liver oil 2 per cent, its deficiencies were fully corrected. This cow was in excellent condition and produced twins weighing 124 pounds.

vitamin A content of the diet. Butter made from the milk of cows on a ration of ground oats and barley, wheat middlings, timothy hay, and oat straw contains less vitamin A than that from milk of cows whose dry feed is supplemented by summer pasture. "June butter" is better in vitamin A value as well as in color and flavor.

Dann in the Nutritional Laboratory at the University of Cambridge found that when the mother's diet was rich in carotene, the amount of vitamin A in the young rat's liver was three times as great as when the mother's diet was lacking in carotene (or vitamin A). The amount of vitamin A which can be transmitted from mother to

offspring is, however, not large, and the best way to insure adequate reserves of vitamin A in the nursling is to administer it directly to the child in addition to a good supply for the mother. The liver at birth varies considerably in the total amount of vitamin A present and since the stores may be low it is good practice to give a vitamin A supplement to all infants soon after the second week.

Hale in 1935 reported the development of abnormalities in pigs where the maternal diet was just sufficient in vitamin A to allow for the completion of gestation. Death or resorption of the fetus occurred if the diet was not adequate for gestation. Warkany and his associates in 1945 reported similar results in rats. They found that when the maternal diet was deficient in vitamin A the normal development of the eyes, lungs, heart, kidney, testes, and diaphragm of the fetus was interrupted. More recently (1953) studies³ showing the prevention of these defects have been reported by Warkany's laboratory when vitamin A was given at different times during the developmental period. Further investigation is needed to study the role of human maternal dietary deficiencies as a cause of congenital malformations.

Resistance to Infection

A surplus of vitamin A in the body is not simply a reserve for some future time of shortage. It is at all times significant for the maintenance of resistance to disease and the development of a high degree of physical vigor. Since 1925 a great deal of experimental evidence has been obtained regarding the character of the changes which lack of vitamin A induces in the various tissues of the body and it has become very clear that epithelial cells, found in the skin and in the mucous membrane in all its ramifications through the respiratory tract, the digestive system, the genitourinary system, the ducts leading from all sorts of glands, and the inner surfaces of many glands, are very quickly altered by deficiency of this vitamin.

Long before any symptoms of disease are apparent, an examination under the microscope of a few cells scraped from the mucous membrane will disclose the drying and deterioration which are incident to the process known as keratinization; or histological examination of the ducts of the sublingual glands, the sebaceous glands of

³ Review. "Malformations Induced by Vitamin A Deficiency." *Nutrition Reviews*, Vol. 12, page 348 (1954).

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the skin, or of the various lachrymal glands of the eye will show them choked with masses of dead cells which have been thrown off from the mucous surface and remained to obstruct the passage. The mucous membrane being thus deprived of its normal secretion offers a good harbor for chance microorganisms which would ordinarily prove harmless. An adequate vitamin A supply at all times is a means of strengthening the natural defenses of the tissues. After damage due to an inadequate supply has been done, dosing with the vitamin will not guarantee a cure, although it may help to hasten such recovery as the tissues are still capable of. Clausen ⁴ of the University of Rochester School of Medicine, studying the influence of vitamin A upon infection in infants, found that among 317 under thirty-six months of age severe infections were twice as frequent in those whose previous diet lacked vitamin A as in those to whose diet it was added in the form of cod liver oil from the age of three months and also in the form of vegetables containing carotene from the age of six months.

Sherman stated "there is much positive evidence that the level of intake of vitamin A does (whether directly or indirectly, primarily or secondarily) influence the frequency, or severity, or duration, of infectious disease—not specifically of any one infection alone, and also not equally of all infections." ⁵

The Eyes

The development of a characteristic eye disease known as xerophthalmia on diets deficient in vitamin A was one of the first observations to be reported. In this the lachrymal gland ceases to function; the eyeball becomes dry and bacteria quickly begin to grow in the conjunctival sac; the lids of one or both eyes become congested, an exudate comes from the inflamed conjunctiva; and soon the swollen, sticky, and scabby lids completely close the eye. If not arrested, the disease eventually attacks the cornea and permanent blindness ensues, unless the animal dies before this stage is reached. This disease is variously known as xerophthalmia, keratomalacia, or conjunctivitis. The upper rat in Fig. 57 and the dog in Fig. 61 show this condition. The relation of the diet to the disease was discovered by Osborne

⁴ Clausen, S. W. "Nutrition and Infection." *Journal of the American Medical Association*, Vol. 104, page 793 (1935).

⁵ Sherman, H. C. *Chemistry of Food and Nutrition*, 8th edition, page 473. The Macmillan Co. (1952).

and Mendel in 1921. They found that 50 per cent of their rats on a diet deficient in vitamin A developed typical symptoms of xerophthalmia.

These laboratory experiences with the white rat stimulated inquiry as to the effect of withholding vitamin A from other species of animals, and xerophthalmia has been experimentally produced in dogs, rabbits, mice, horses, swine, guinea pigs, chickens, and monkeys.



(Courtesy of Drs. H. Steenbock, V. E. Nelson, and E. B. Hart)

Fig. 61. Xerophthalmia in the Dog

Such experiences inevitably turned attention to eye disease occurring in the human race, with a view to its possible correlation with dietary deficiency. Diseases of the eye have afflicted mankind since time began and are mentioned in the ancient medical literature of Egypt, China, and Greece, but the first person of modern times to show a definite connection between xerophthalmia and diet appears to have been a Japanese physician named Mori, who published in German a report of the so-called "Hikan," an eye disease of which, at a time of food shortage, he had observed nearly 1,500 cases among children from two to five years of age. This he believed to be due to the lack of fat, as it was curable (if it had not progressed too far) by the administration of chicken livers, fish livers, or eel fat, and also of cod liver oil, all of which, we now know, are rich in vitamin A.

Other illuminating experiences were recounted 13 years later

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(1917) by Bloch⁶ of Copenhagen, who had personally observed during the years from 1912 to 1916 many cases of xerophthalmia among children of the Danish poor. The most severe cases were among children about a year old, who had been fed chiefly skim milk practically free from fat, along with oatmeal and barley soup, and who were threatened with blindness owing to ulceration of the cornea. As the children were greatly undernourished, whole milk was prescribed together with liberal doses of cod liver oil. The result was a rapid disappearance of the eye trouble and a complete cure whenever the destruction of the cornea had not gone too far. In 1918, upon the introduction by government action of butter into the dietary of the poorer people, xerophthalmia was practically wiped out of Denmark.

Xerophthalmia is still prevalent in the Far East, where the diet of the poor is usually very low in vitamin A. In the clinic of the Peiping Union Medical College in China, out of 154 patients with this disease whose diets were known, 29 had no apparent source of the vitamin and 110 practically no vitamin A except what they obtained from white cabbage.⁷ In harmony with laboratory experience with animals, the greatest sufferers are the children, although another rise in the incidence of the disease comes in early adult life when hard work and poor food undermine health. Not only in China but also in India, Ceylon, and other parts of the world it is the chief cause of many cases of blindness, especially among the children. The dryness of the eyes is such that the children are very often seen moistening their eyes with saliva. Pal in 1949 referred to 150 cases observed in an out-patient clinic in Calcutta during a six-month period with a high incidence of xerophthalmia and night blindness.

Xerophthalmia is a symptom of severe deficiency of vitamin A and does not occur commonly in the United States, but Kruse⁸ reported that mild grades of this condition, due to too low an intake of the

⁶ Bloch, C. E. "Eye Disease and Other Disturbances in Infants with Deficiency of Fats in the Food." *Journal of the American Medical Association*, Vol. 68, page 1516 (1917).

⁷ Sweet, L. K., and K'ang, H. J. "Clinical and Anatomic Study of Avitaminosis A among the Chinese." *American Journal of Diseases of Children*, Vol. 50, page 699 (1935).

⁸ Kruse, H. D. "The Ocular Manifestations of Avitaminosis A, with Especial Consideration of the Detection of Early Changes by Biomicroscopy." *U. S. Public Health Reports*, Vol. 56, pages 1301-1324 (1941) and *The Milbank Memorial Fund Quarterly*, Vol. 19, pages 207-240 (1941).

vitamin, may occur fairly often. He frequently found a condition of dryness in the mucous membrane which covers the outer surface of the eyeball and lines the eyelids, along with triangular white spots (known as Bitôt's spots) on the conjunctival membrane of the eye. These conditions cleared up when no change other than that of increasing the intake of vitamin A was made. Sandels, Cate, Wilkinson, and Graves⁹ in a study of school children in Florida noted many cases of conjunctivitis among them and obtained prompt improvement when the vitamin A intake of the children was increased.

Night blindness (nyctalopia or hemeralopia), which is the inability to see clearly in a dim light especially after exposure to an intense one, has been observed wherever xerophthalmia has occurred and probably represents the earliest manifestation of a vitamin A deficiency. Thus, slaves in Brazil, according to an 1883 report, were unable to see when returning from their work after sunset, although strangely enough they had no difficulty in setting out again before sunrise in the morning when it was actually much darker than on the previous evening. According to Mason¹⁰ the "impairment of vision in dim light manifests itself as sensitivity to bright light, difficulty in reading unless the light is brilliant, glittering images and dancing specks before the eyes, tendency to stumble or to bump into objects in dim light, and prolonged delay in adaptation from bright to dim light. These defects are much more marked in evening twilight than in the dim light of daybreak."

This condition was demonstrated by Fridericia and Holm at the University Institute of Hygiene in Copenhagen in 1925. The disease was at that time known to be due to an anomaly in the rod cells of the retina, which consisted in inability of visual purple, which is bleached in light, to regenerate quickly. So these investigators set out to compare the visual purple in the retinas of normal rats with that of rats given a diet lacking vitamin A to see whether this lack was the cause of the difficulty. When the growth curves showed that

⁹ Sandels, M. R., Cate, H. D., Wilkinson, K. P., and Graves, L. J. "Follicular Conjunctivitis in School Children as an Expression of Vitamin A Deficiency." *American Journal of Diseases of Children*, Vol. 62, page 101 (1941).

¹⁰ Mason, K. E. "Effects of Vitamin A Deficiency in Human Beings." Article in Sebrell, W. H., and Harris, R. S. *The Vitamins*, Vol. I, Chap. I, Sect. VIII. Academic Press, Inc. (1954).

the vitamin A reserve was exhausted, the depleted animals were taken from a dark room and exposed to a brilliant light, by which the visual purple was completely bleached in two hours, the same time required for bleaching in case of the normal controls. Measurements of the visual purple showed that the time in which the color was completely regained when they were returned to the dark room was very much shorter in the normal animals than in those deprived of vitamin A. When it was learned that the retina is rich in vitamin A, the value of tests of speed of recovery of the visual purple after exposure to light as a means of detecting vitamin A deficiency began to receive special attention.

During World War I an ophthalmologist, Birch-Hirschfeld, had devised a test used on soldiers in the German army that measured the impairment of vision in a dim light, and in 1934 this was adapted by Jeans to the study of the eyes of school children as a possible means of determining their vitamin A reserves, its practicability resting upon the fact that slowness in regeneration of the visual purple is one of the common early symptoms of vitamin A deficiency. The test was applied to orphanage children and to a large number of Iowa school children, in rural, village, and urban homes, on different economic levels. Using the biophotometer to measure dark adaptation ability, Jeans¹¹ and his associates found the greatest incidence of abnormal results in slightly less than 20 per cent of a group of 120 children in the winter, while in late spring the incidence was reduced to about 2 per cent in a group of 50. The orphanage groups failed to show this seasonal variation. Jeans also observed the relation of the deficiency of vitamin A to the seasonal occurrence of infections. These findings emphasize the need for providing generous amounts of vitamin A for school children during the winter months. Similar studies in Canada, Sweden, and Denmark showed that many children who appeared perfectly normal were not having as liberal amounts of vitamin A as are necessary to keep the visual purple of the retina functioning at its best at all times.

Other investigators have reported less consistent results with the biophotometer than those reported by Jeans and his associates. However, Jeans called attention to the importance of the technique used

¹¹ Jeans, P. C., Blanchard, E. L., and Satterthwaite, F. E. "Dark Adaptation and Vitamin A." *The Journal of Pediatrics*, Vol. 18, page 170 (1941).

and the application of certain interpretations if the results are to be consistent from test to test of the same subject and correspond with the vitamin A status of those subjects. Various types of adaptometers and biophotometers have been used to measure dark adaptation and more recent work points out the necessity of ample time and trained personnel if the instruments are to be effectively used and satisfactory results obtained.

Some investigators have reported that the vitamin A content of the blood responds more promptly and characteristically to changes in vitamin A intake than do the eyes of the same subjects in the dark adaptation test. However, more information is needed in regard to the normal range of values for vitamin A and carotene in the blood. Bessey has suggested that the normal concentration of vitamin A ranges from 30 to 70 micrograms per 100 milliliters of blood, while other investigators have suggested 20 micrograms (70 I.U.) as the lower limit of the normal range.

The Respiratory Tract

The changes in epithelial tissue when vitamin A is lacking have nowhere been more clearly demonstrated than in the mucous lining of the respiratory tract. Here, in addition to the shrinking, hardening, and general deterioration of the cells, resulting in dry, roughened surfaces lacking their normal protective secretions, there is also loss of the cilia which by their constant movement aid in keeping the surfaces clean. In the very detailed studies of vitamin A deficiency in China made by Sweet and K'ang, the most frequent symptoms, next to those in the eye, were found in the larynx and the trachea and sometimes even in the bronchi. In studies in this country on infants, Wolbach of the Harvard Medical School, to whom much of our knowledge of the influence of vitamin A on epithelial cells is due, and Blackfan, a leading pediatrician of the same school, also noted that the earliest appearance of keratinization was in the upper part of the respiratory tract.¹²

These human findings are in agreement with many observations on laboratory animals under carefully controlled conditions. As long ago as 1923, Daniels of the Child Welfare Research Station at Iowa

¹² Blackfan, K. D., and Wolbach, S. B. "Vitamin A Deficiency in Infants, Clinical and Pathologic Study." *Journal of Pediatrics*, Vol. 3, page 679 (1933).

City, Iowa, called attention to the occurrence of snuffles and labored breathing in young rats on diets deficient in vitamin A. In a colony of between 400 and 500 animals, those on the low vitamin A diets were the only ones that ever manifested such symptoms, and if, after they appeared, change to an adequate supply of the vitamin was made in time, "the appetite improved, the snuffles disappeared, and the animals gained in weight." Even before there was any evidence of physical breakdown, while the animals were still gaining in weight and there were no signs of nasal inflammation, there was found on autopsy marked congestion of the nasal passages and pus in the middle ear and at the base of the tongue.

If the deprivation of vitamin A is postponed until young rats are two months old, instead of being instituted at the age of one month, they are less susceptible to xerophthalmia, but more of them show lung infections. The tendency of laboratory animals to break down with lung disease at an age corresponding to that at which pulmonary tuberculosis so often develops in young men and women is of great interest. Getz and Koerner have shown a correlation between a deficiency of vitamin A and the incidence of tuberculosis. The death rate from tuberculosis in Denmark rose early in World War I but declined sharply following the war, when abundant supplies of milk, butter, and meat were again available. Wohl has suggested that in addition to a protein deficiency, the deficiencies of vitamins A and ascorbic acid appear to be in proportion to the extent of the tuberculosis involvement. In 1944, in the survey made in Newfoundland,¹³ tuberculosis was prevalent along with indications of poor nutrition. The report of the study made of the Canadian Bush Indians¹⁴ also showed similar relationships.

It must also be remembered in this connection that infection tends to interfere with utilization of the vitamin and to cause depletion of body reserves, and also that organisms usually harmless may become quite harmful if the subject has already a low resistance to infection. How these facts relate to such a malady as the common cold is a

¹³ Adamson, J. D., Jolliffe, N., Kruse, H. D., Lowry, O. H., Moore, P. E., Platt, B. S., Sebrell, W. H., Tice, J. W., Tisdall, F. F., Wilder, R. M., and Zamecnik, P. C. "Medical Survey of Nutrition in Newfoundland." *Canadian Medical Association Journal*, Vol. 52, page 227 (1945).

¹⁴ Moore, P. E., Kruse, H. D., Tisdall, F. F., and Corrigan, R. S. C. "Medical Survey of Nutrition among the Northern Manitoba Indians." *Canadian Medical Association Journal*, Vol. 54, page 223 (1946).

matter of great interest, since so many days of absence from school or work are caused thereby. Cameron at the University of West Virginia contributed a two-year study of the incidence and duration of colds among more than 200 college students. These young men and women were not eating diets deficient in vitamin A, for careful records showed a daily consumption which would be regarded as decidedly liberal for normal adults. In addition to their usual diet, part of them received daily one tablespoonful of standard cod liver oil; another part, carotene in oil; a third part, tablets containing a cod liver oil concentrate; and a fourth part, tablets of plain milk sugar with no vitamin A whatsoever. With the exception of those taking the cod liver oil no one knew whether he was getting vitamin A or not. The number of colds and their duration were compared for all students getting over 7,000 International Units of vitamin A daily with the records of those receiving less than this amount. The former averaged 2.4 colds per person of 17.7 days' duration as against 2.8 colds per person of 22.6 days' duration. A similar study, including students in the School of Medicine of Western Reserve University, and members of the hospital staff and nursing group, made by Shibley and Spies included 241 young adults who were divided into three groups, one receiving halibut liver oil, another corn oil with no vitamin A, and a third vitamin D in oil but no vitamin A. No one knew to which group he belonged. As in the Cameron study there was no difference in susceptibility to colds, the average number being about the same in the three groups, but there was a definite shortening of several days in the duration of the colds in the group taking vitamin A.

These studies, together with the more technical ones on the changes actually taking place in the tissues, make it clear that vitamin A is distinctly a nutrient and not an antiseptic; that its function is to keep the epithelial cells of the mucous membrane in the best possible condition so that the natural defenses of the organism will be preserved. Sherman suggested that at least four times the amount actually required for apparent health may bring a good return in health protection.

The Urinary Tract

When animals are kept for some time on diets low but not entirely lacking in vitamin A, kidney and bladder stones are frequently

found. They have not been found in animals on other types of deficient diet. In chicks, however, lack of vitamin A affects the kidneys, interfering with the elimination of waste. McCarrison,¹⁵ in 1931, reported that certain areas of India, particularly in the northwest, were known as "stone areas" because of the prevalence of kidney stones among the people. He described it as a "poor man's disease," occurring among those whose chief dietary staple was cereal and most frequently where vegetation was relatively scanty, where grazing for cattle was poor, and where wheat was the chief food crop. McCarrison produced calculi in rats in 90 days from weaning time on diets low in vitamin A and consisting chiefly of wheat. The addition of milk at the rate of $\frac{2}{3}$ ounce per rat per day, or of butter or cod liver oil completely prevented the disease, but vegetable oils which lack vitamin A were ineffective. McCarrison pointed out that urinary excretion was more copious on a diet rich in vitamin A, and that this might help to flush out the kidneys and reduce the tendency for phosphates to accumulate.

Even if kidney stones are not now recognized as a common result of dietary deficiency among the people of America, who are on the whole so much better nourished than the masses of India, there seems to be every reason to believe that many kidney disturbances of middle life and old age have their origin in subacute infections, repeated perhaps many times before any obvious pathological condition develops. It is certainly the part of wisdom to keep such valuable organs in the best possible condition through a regular and liberal vitamin A intake throughout adult life as well as during the period of growth.

The Alimentary Tract

Since it has been fully established that the mucous membrane is very quickly affected by shortage of vitamin A, changes in the alimentary tract are as likely to occur as in the respiratory or genito-urinary tracts. In rats sufficiently depleted to begin to lose weight, diarrhea and other signs of digestive disturbance have often been observed, and in monkeys these are sometimes so severe as to cause death before any signs of xerophthalmia appear. An interesting experiment to test the efficiency of the mucous membrane in guarding

¹⁵ McCarrison, R. "A Lecture on the Causation of Stone in India." *British Medical Journal*, No. 1, page 1009 (1931).

against the invasion of the body by bacteria has shown that organisms will not pass through nearly so readily when the body is well protected by vitamin A. The normal controls and the depleted animals were each given the same dosage of the bacteria producing mouse typhoid by means of a stomach tube. At various intervals of time they were killed and the kidneys, spleens, livers, and lungs examined to see how many of the microorganisms had been able to migrate through the intestinal wall in order to reach these organs. The results of examining them at the end of a nine-hour period is shown below.

PER CENT OF RATS SHOWING INVASION OF BACTERIA NINE HOURS AFTER ADMINISTRATION BY STOMACH TUBE

<i>Organ Examined</i>	<i>Normal Controls, Per Cent</i>	<i>Vitamin A-Deficient Rats, Per Cent</i>
Kidney	33	80
Spleen	16	66
Liver	38	93
Lung	38	86

A study of the tissue changes made by Richards of the Rowett Research Institute, Scotland, demonstrated clearly the very short time required for pathological symptoms to develop in rats deprived of vitamin A. Here, too, roughened surfaces, clogged ducts, and lack of the normal moistening by secretions lead to inflammation of the whole intestinal tract and to marked alterations in the stomach lining, with pittings, hemorrhages, and in many instances, actual ulceration.

The relation of all this to the human situation is not yet established. One of the physicians at the Peiping Union Medical College described a case of greatly diminished gastric secretion which was restored to normal by the administration of cod liver oil, and Blackfan and Wolbach reported changes in the epithelium of the alimentary tract of the infants studied by them. Such observations tend to strengthen the view that vitamin A is essential to the full functioning of "the first line of defense," the mucous membrane, in the digestive tract.

The Skin

China has been a most interesting field for the study of vitamin A deficiencies because of the very low vitamin A intake of the poorer

people. During the winter and spring of 1928, Frazier and Hu¹⁶ of the Peiping Union Medical College observed 15 cases of vitamin A deficiency among young Chinese soldiers garrisoned in villages about Peiping, all of whom had xerophthalmia, and also a peculiar skin disturbance. Their diets consisted chiefly of rice, maize, millet, white cabbage, and salted vegetables. Meat, eggs, and green vegetables were never eaten oftener than once a month and by some of them not at all.

The skin was dry and rough, and at the sites of the hair follicles a pimply eruption occurred, spreading over the upper and lower extremities, shoulders, abdomen, chest, and back. There was a typical clogging of the sebaceous glands, so that a dry, firm papule containing a plug of hardened epithelial cells projected above the surface of the skin. Inflammation developed, due to the irritation, and sometimes small ulcers formed. The skin of the face was dry and covered with acne-like pimples, which were large and conspicuous. When the patients were put on an adequate diet and given three tablespoons of cod liver oil daily, the skin became moist, as the sweat glands began to function again, the papules lost their horny cores, and in the course of four to six weeks the pits so formed gradually shrank and disappeared.

An almost identical report was made by Loewenthal,¹⁷ Medical Officer of the Mulago Hospital, Kampala, East Africa, who found that out of 81 prisoners with night blindness or xerophthalmia, 74 had cutaneous eruptions as described above. Upon treatment with three tablespoonfuls of cod liver oil daily for nine weeks, with no other change in the diet, 98 per cent of the cases cleared up. Additional evidence that vitamin A was the curative factor was furnished by 2 patients who were given an extract containing vitamin A only and these, too, were cured within the same period.

Indications of the same tendency were reported by Helen Mackay in a study of 118 London babies from poor homes. Half of the children were kept on their usual diet of dried milk with one teaspoonful of orange juice daily, while the other half were given additional

¹⁶ Frazier, C. N., and Hu, C. K. "Cutaneous Lesions Associated with Vitamin A Deficiency in Man." *Archives of Internal Medicine*, Vol. 48, page 507 (1931).

¹⁷ Loewenthal, L. J. A. "A New Cutaneous Manifestation in the Syndrome of Vitamin A Deficiency." *Archives of Dermatology and Syphilology*, Vol. 28, page 700 (1933).

vitamin A. The vitamin A furnished by the milk and orange juice was sufficient for the control group to grow at practically the same rate as the group whose diet was enriched with vitamin A, and the only outstanding difference was in the condition of the skin. Twice as many babies developed local irritation with an infection by local organisms of low virulence in the group with the lower vitamin A intake, so that Mackay concluded that skin disturbance might be one of the earliest signs of vitamin A deficiency.

In Ceylon, where the diet of the poor is exceedingly low in vitamin A, the children are not only afflicted with xerophthalmia and night blindness, but also with an inflamed and coarsened condition of the skin known as "toad-skin," which clears up on administration of cod liver oil.

In the Minnesota experiment conducted by Keys¹⁸ and his associates, the effects of a submarginal intake of vitamin A (1810 I.U. daily) was reported in 24 of the 31 subjects maintained on a partial starvation diet for twenty-three weeks. Carotene furnished the chief source of vitamin A since the diet was low in fat. These subjects developed a mild to moderate papular eruption of the skin resembling a vitamin A deficiency. The skin became dry and scaly and the hair lusterless.

In the Medical Resurvey of Nutrition in Newfoundland in 1948, Aykroyd¹⁹ and his associates observed a significant reduction (5.2 per cent) in the number of natives showing folliculosis of the skin. This was accounted for by the fortification of the margarine with vitamin A and the distribution of cod liver oil to 55,000 grade-school children in a quantity sufficient to provide one teaspoonful daily to each. Some doubt was expressed regarding the actual ingestion of the cod liver oil since it was regarded as a product of the fisheries and consequently possessed less prestige in Newfoundland. Even greater improvement might have been shown if each child had actually consumed his share of the cod liver oil. There was also a

¹⁸ Keys, A., Brozek, J., Henschel, A., Michelsen, O., and Taylor, H. L. *The Biology of Human Starvation*, Vols. 1 and 2. University of Minnesota Press, Minneapolis (1950).

¹⁹ Aykroyd, W. R., Jolliffe, N., Lowry, O. H., Moore, P. E., Sebrell, W. H., Shank, R. E., Tisdall, F. F., Wilder, R. M., and Zamecnik, P. C. "Medical Resurvey of Nutrition in Newfoundland, 1948." *Canadian Medical Association Journal*, Vol. 60, page 1 (1949).

significant reduction in the incidence of dry, "staring" hair among the children.

Dryness and roughness of the hair is an early symptom of vitamin A deficiency. With the administration of vitamin A, improvement is marked in a very short time, the hair becoming soft and glossy again.

The Teeth

The outstanding researches of Wolbach of Harvard University and Howe of the Forsyth Dental Infirmary in Boston have made it clear that vitamin A exercises a very definite control over tooth development.²⁰ When rats are placed on a diet lacking vitamin A, their

teeth become chalky, white, and brittle, owing to the loss of the enamel with its orange-colored pigment and the exposure of the dentine. The development of the enamel is controlled by the enamel organ, a complex structure of epithelial origin, which begins to degenerate as soon as vitamin A is withheld. The formation and maintenance of the dentine depends upon the odontoblasts, a single layer of very active cells arranged in an orderly row between the pulp and the dentine, and sending filaments into both.

The changes in the enamel organ affect the odontoblasts first on the side opposite to the enamel organ and the dentine on that side becomes thin and defective while increasing on the other side, so that the tooth in cross section becomes much distorted. Eventually all the odontoblasts shrink and shrivel and the dentine as well as the enamel becomes strikingly

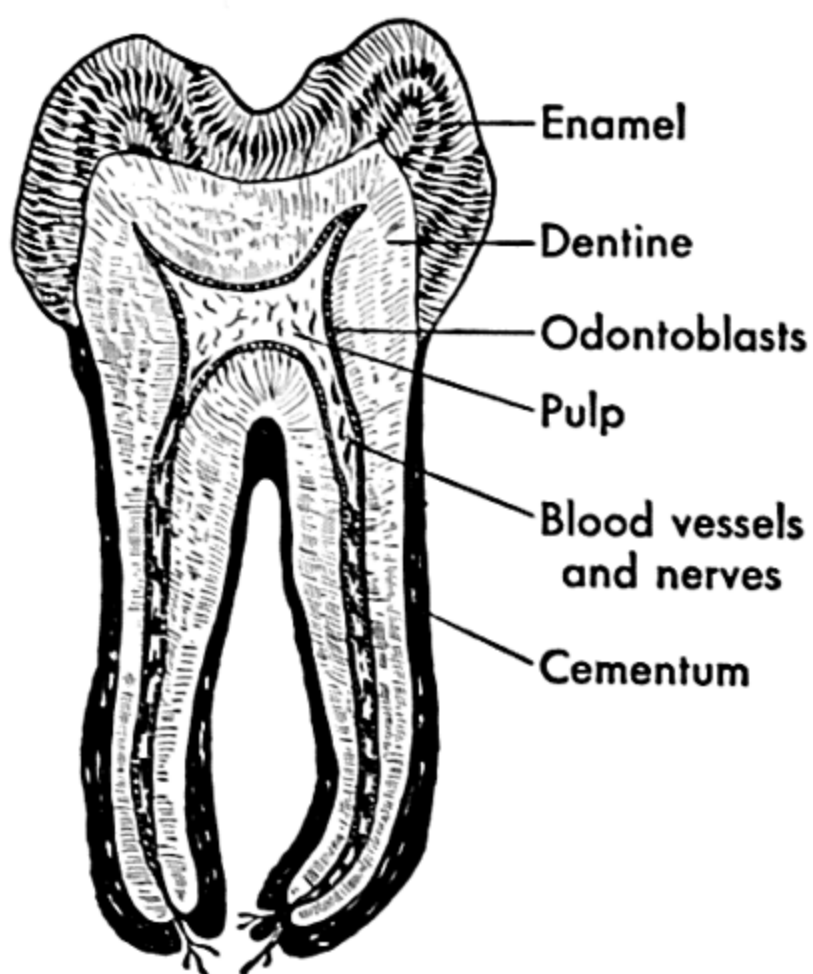


Fig. 62. A Diagram Showing in Cross Section the Relationship of Parts in a Tooth

²⁰ Wolbach, S. B., and Howe, P. G. "The Incisor Teeth of Rats and Guinea Pigs in Vitamin A Deficiency and Repair." *American Journal of Pathology*, Vol. 9, page 275 (1933).

defective.²¹ These findings have been confirmed and extended by Schour, Hoffman, and Smith.²²

The health of the teeth is not only affected by these controlling organs within the structure of the tooth itself but also by the soft tissues in which they are imbedded, upon which proper position in the jaw and freedom from bacterial invasion of the gums to a very considerable degree depend. In England Lady Mellanby studied for many years the effect of vitamin A on the teeth of rats and puppies, and her conclusion with regard to vitamin A follows: "It is of fundamental importance to include vitamins A and D in the diet during the early developmental period if the periodontal tissues are to resist disease. A large supply of these vitamins during a later period even from the fifth month onwards, does not compensate for a deficiency during the earlier period. Vitamin A in very large doses may prevent the spread of the pathological condition."²³

Reviewing the effects of vitamin A deficiency on the teeth, Bessey and Wolbach concluded that "in all probability, vitamin A deficiency during the formative period of teeth outranks in the human being all other vitamin deficiencies in importance."²⁴

The Nervous System

When animals have been completely deprived of vitamin A at weaning time, they grow until their body reserves are exhausted and then decline rapidly and die in a short time. But if they are given small amounts of vitamin A after depletion they will live for eight or ten weeks, and then succumb to incoordination, muscular weakness, and paralysis. Early observers of these symptoms attributed

²¹ For a detailed description of the structure and development of the teeth consult Mellanby, May. *Diet and the Teeth, Part III. The Effect of Diet on Dental Structure and Disease in Man*. Medical Research Council, Special Report Series No. 191. His Majesty's Stationery Office, London (1934); and Bodecker, C. F. "Nutrition of the Dental Tissues." *American Journal of Diseases of Children*, Vol. 43, page 416 (1932).

²² Schour, I., Hoffman, M. M., and Smith, M. C. "Changes in the Incisor Teeth of Albino Rats with Vitamin A Deficiency and the Effects of Replacement Therapy." *American Journal of Pathology*, Vol. 17, page 529 (1941).

²³ Mellanby, M. *Diet and the Teeth, Part II*, page 31. Medical Research Council. Special Report Series No. 153. His Majesty's Stationery Office, London (1930).

²⁴ Bessey, O. A., and Wolbach, S. B. *The Vitamins*, page 46. American Medical Association (1939).

them to other causes, but in 1928 Hughes and his associates at the Kansas Agricultural Experiment Station found that pigs placed at weaning on a diet deficient in vitamin A developed unsteadiness of gait in six to seven months, and could be cured by addition of cod liver oil to their diet. Examination of the nervous system showed some very marked degenerative changes. Again, in 1932, Elvehjem and Neu, at the University of Wisconsin, depriving day-old chicks of vitamin A, found that one of the most striking results was the development of a staggering gait and finally paralysis as shown in Fig. 63. This same year, Krauss and his associates at the Ohio Agri-



Fig. 63. These two rats are the same age. The upper one had an adequate diet, the lower one a diet lacking vitamin A. The animals are trying to stand on a slanting wire screen. The upper one has no difficulty in spreading its hind legs to maintain its position but the lower one has paralysis in the hind leg exposed and is unable to use it.

cultural Experiment Station, trying to maintain rats on very low vitamin A levels, found that after 40 to 50 days over half of the animals showed paralysis in their hind legs, and great weakness and wasting of the muscles. A detailed study of the nervous system revealed degenerative changes in the spinal cord and in the medullary sheaths of the sciatic and vagus nerves. In 1936 Zimmerman and Cowgill of Yale University reported similar effects in a group of 43 rats and found in addition that although adequate doses of carotene administered relatively early in the course of the deficiency brought about resumption of normal growth and disappearance of xerophthalmia, the signs of the nervous disturbance persisted. It was found on dissection that the changes in the nervous system were, if anything, more marked than in the untreated animals. This was attributed to inability of the nervous system to regenerate once it has been severely injured.

Wolbach and Bessey found another explanation for these disturbances of the nervous system. They found that in young animals on a vitamin A-deficient diet skeletal growth is retarded before rate of increase in weight is affected while the central nervous system and other soft tissues of the body grow at approximately the normal rate until body weight becomes stationary. The result of this disproportion between the growth of the bony and nervous systems is an overcrowding of the brain and spinal cord which causes degeneration of nerve roots, peripheral nerves, and nerve fibers in the spinal cord and brain. They concluded that "the nervous lesions of vitamin A deficiency thus are wholly mechanical in origin."

Measurement

The vitamin A value of foods can be determined by a number of methods. Vegetable sources contain only the provitamins (precursors) of vitamin A while animal sources contain both vitamin A and the provitamins; consequently the method used must be suitable for the food at hand. A number of color reactions are used to demonstrate the presence of vitamin A or its precursor and of these the Carr-Price reaction (solution of antimony trichloride in pure chloroform) which gives a blue color if the vitamin or provitamin is present is probably the best known. A blue color may result with other compounds as well as with vitamin A so care must be used in

interpretation of results. The measurement of the intensity of the blue color (indicating the amount of vitamin A) can be carried out with the spectrophotometer and other instruments. The paper chromatographic method is another means of determining the vitamin A present in a sample of food. The determination of vitamin A in foods presents many problems which are a challenge to the most experienced chemists and the solving of these should be left to them.

Biological assays are also made. One of these consists in using equal numbers of male and female rats, 20 to 22 days of age and weighing between 30 and 40 grams. They are placed on a standard vitamin-deficient diet for six to seven weeks until growth ceases and the first symptoms of xerophthalmia appear. The food to be tested is then given daily in suitable amounts and the weight gains observed for at least four weeks. These results are compared with the results of feeding a standard preparation of a known quantity of vitamin A.

Students who are interested in the details of these methods and others are referred to the United States Pharmacopeia and textbooks of biochemistry.

Sources

Vitamin A was first discovered in animal fats (butter, egg yolk, and cod liver oil). But very shortly the green leaves of alfalfa, cabbage, spinach, and young clover, were also found to be good sources and eventually Drummond showed that the cod and other fishes derive their vitamin A from small marine animals which in turn get it from various minute marine plants, algae, and the like. Thus the dependence of the animal upon the plant for vitamin A was established. Now we know that plants have only the provitamin A or carotene. Fish and herbivorous animals can transform carotene into vitamin A but many carnivorous animals are dependent upon the preformed vitamin A. As has been previously stated it is desirable to speak of the vitamin A value of foods rather than the vitamin A content.

When seeds are sprouted in the absence of light, little, if any, provitamin A (carotene) is produced, but as soon as the sprouts come to light and their tips begin to turn green, provitamin A is rapidly formed. Leaves which do not turn green, such as the inner leaves of lettuce and cabbage, are not nearly so rich a source of the

vitamin as the green parts. In general the thinner and greener a leaf is, the better source it is likely to be.

The storage parts of plants, as thickened roots or tubers, and the endosperm of seeds, are relatively poor sources but there is much variation among individual plants; yellow corn is richer than white; sweet potatoes are richer than white ones: and carrots have a higher value than either white or yellow turnips. Of the fruits, apricots, cantaloupes, yellow peaches, and papayas are among the best sources.

Milk stands pre-eminent among food materials as a source of vitamin A. The value of the milk and the butter made from it is influenced by the diet of the cow, milk produced in the summer when the animal is furnished a plentiful supply of green food being richer than the winter product; but in practice this difference is much less than is generally supposed, because most milk comes from cows which get good hay or ensilage in winter.

The storage of vitamin A in the tissues of animals has already been referred to. Muscle contains very little under the most favorable feeding; glandular organs contain more, the liver being richest of all. Egg yolk resembles butter in its high content. Fish liver oils are very rich in vitamin A but vary widely among themselves. During World War II there was a great scarcity of vitamin A and this led to an extensive search for new natural sources. As a result the liver oils of many fish not previously used were found to be excellent sources. Halibut liver oil had been found to be a more potent source than cod although the Ling cod liver oil is now recognized as one of the richest of all fish liver oils and the California jewfish liver oil tops the list. The liver oils of the soup-fin shark, the black cod or sablefish, the red and black rockfish, the stone bass, and the swordfish all rate very high as sources of vitamin A.

Vitamin A in animal fats loses its potency gradually on exposure to air and more rapidly when thoroughly aerated, especially if the temperature is raised. As it exists in plant tissues it is not so easily oxidized and withstands ordinary cooking temperatures without marked loss. Figure 64 shows the comparative vitamin A values of some of our common foods. Additional information regarding the vitamin A value of foods will be found in Tables II and IV in the Appendix.

Requirement

The necessity for a liberal supply of vitamin A in the human diet has been established beyond doubt. The next important question is how much is required for the best protection? We have already seen that requirements are high in periods of rapid growth, in pregnancy, and lactation. Also in illness special diets should be so planned as not to deprive the patient of any vitamin.

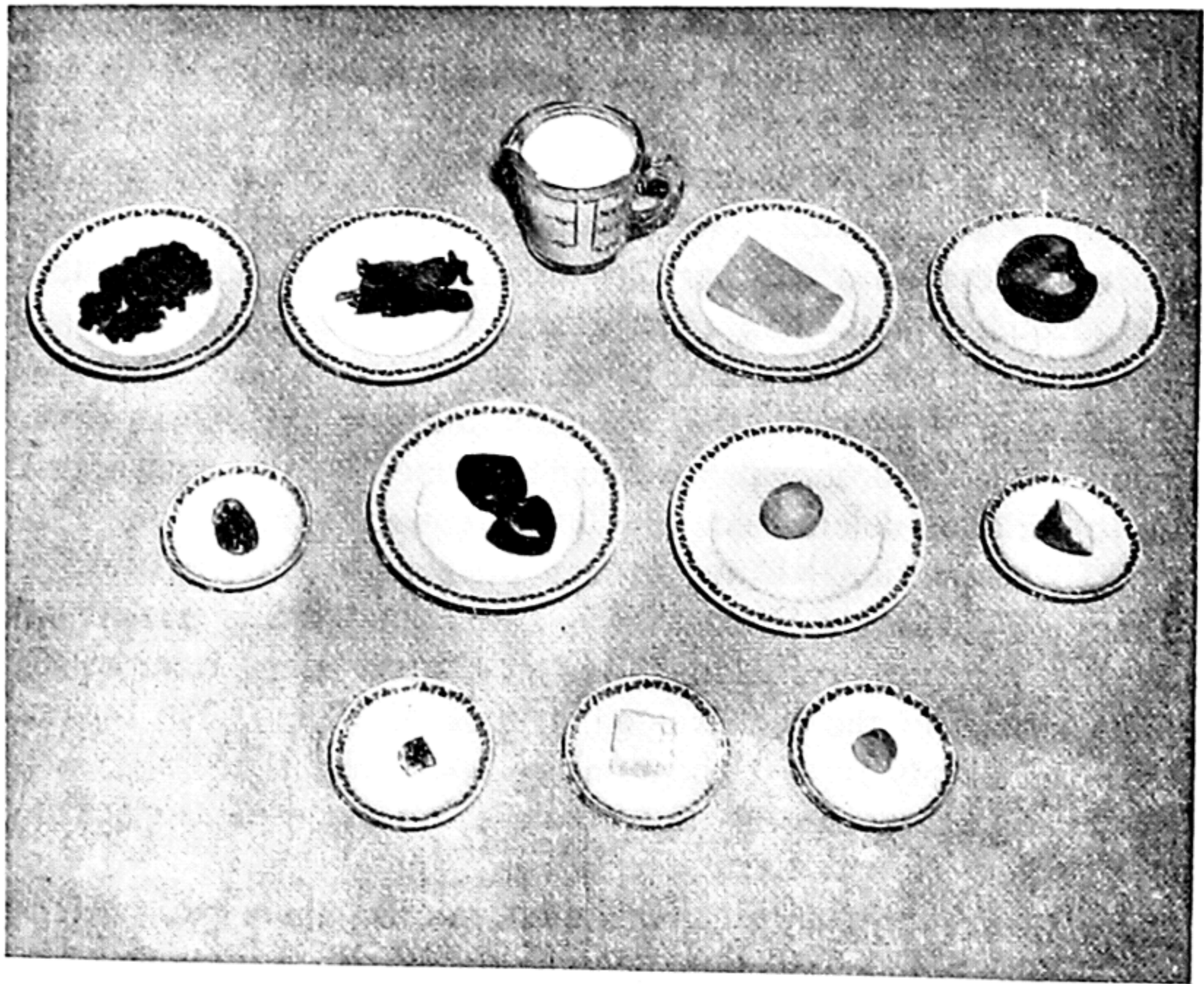


Fig. 64. Food Portions Yielding 468 I.U. (Three Shares) of Vitamin A

Grams		Grams	
Kale	5	Kidney, beef	41
Spinach	5	Egg yolk	13
Milk, whole	250	Sweet potato	6
Cheese, Cheddar	33	Liver, calf	2
Tomato	42	Margarine	14
Apricot, dried	6	Carrot	4

The two sources of vitamin A in our diets, (1) the preformed vitamin, and (2) the provitamin or carotene, have already been dis-

cussed. It has been estimated that only one-third of the vitamin A in the average American diet occurs as the preformed vitamin, the other two-thirds occurring as the provitamin. A great variation in the availability of the carotene has been observed depending upon the source and the other substances in the diet. Evidence indicates that carotene is converted into vitamin A in the intestinal wall.

The requirements for vitamin A are expressed as International Units (I.U.). See page 216 for the discussion of the International Unit. The method which has been used to measure the minimal daily adult human requirement for vitamin A is that of determining the least amount of the vitamin which will just prevent night blindness but not produce significant storage. Booher and her associates at the Bureau of Home Economics of the United States Department of Agriculture reported results obtained on adult human subjects who were kept on a diet very low in vitamin A value (but otherwise adequate) until their eyes became incapable of adapting normally to darkness as revealed by the visual adaptometer. Cod liver oil of known vitamin A value was then added to the diet in graded amounts and the dose which would just bring about normal adaptation to darkness determined. The doses required ranged from 1,750 to 3,850 International Units per day when figured to 70 kilograms of body weight. Night blindness was again developed in the subjects and then carotene crystals dissolved in cottonseed oil were administered instead of the cod liver oil. It took 3,010 to 7,210 International Units daily for 70 kilograms of body weight to bring about normal adaptation, showing that carotene was not used as efficiently as vitamin A.

The Medical Research Council of Great Britain²⁵ has reported prophylactic and curative tests on young adults when carotene represented the sole source of vitamin A and obtained a minimal daily requirement of 1,500 I.U. of beta-carotene assuming that all carotene given was absorbed. This was increased to 3,000 I.U. to allow for individual variation. The minimal adult requirements with a margin of safety suggested in this report was 2,500 I.U. of vitamin A and 3,000 I.U. of beta-carotene in oily solution. It was also suggested that 7,500 I.U. of carotene would be required if green vegetables provided the sole source.

²⁵ Hume, E. M., and Krebs, H. A. (Editors). Medical Research Council. Special Report Series No. 264. London (1949).

Sherman and his associates in full-life experiments with laboratory animals demonstrated increased benefits to the animal as the vitamin A intake was increased up to four times that of a minimal adequate diet, indicating how great the difference may be between the minimal and optimal values for vitamin A content of the diet.

Children and pregnant and lactating women have relatively higher requirements for vitamin A than average adults. Out of a consideration of such evidence as was at hand regarding human requirements for vitamin A, the Food and Nutrition Board of the National Research Council in 1953 proposed the Recommended Daily Dietary Allowances given in Table III(a) of the Appendix. These recommendations are similar to those made in 1948 and assume that the diet is made up of natural foods contributing two-thirds of the total vitamin A as carotene and one-third as the preformed vitamin. In the chapters on construction of diets for various ages and groups will be found information as to the foods which should be used to meet these recommendations. Since the capacity for storage of vitamin A is very great, still more liberal amounts may be a good health investment. Sherman said: "It seems wise for those who can afford it to invest rather liberally at all ages in food rich in vitamin A, knowing that in this case the body will store the surplus to an extent and with an efficiency which is not to be expected in the case of most other nutrients."

Hypervitaminosis A

This chapter would not be complete without a word of warning in regard to the possibility of taking too much vitamin A lest in our zeal to keep our stores of vitamin A at the optimum we overdo a good thing. Our readily available vitamin capsules and vitamin A concentrates make it easy to take large amounts of vitamin A and there are on record in the medical literature many cases where this has happened and toxic effects have resulted. If one pays attention to the labels on the packages of reputable drug companies or carefully follows the recommendations of a physician there should be no danger of getting too much.

A great excess of vitamin A in an early period of growth may result in an acceleration of skeletal growth. Effects of hypervitaminosis A have been observed in man and a number of experimental animals. In adults the early toxic effects may cause headache, vomiting,

diarrhea, etc. In infants a scaly dermatitis, patchy loss of hair, irritability, anorexia, and skeletal pain may occur.

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Thiamine

Discovery

For centuries there has been widespread in the Orient a nerve disease called beriberi, said to have been known to the Chinese as early as 2600 B.C. The Malay States, Thailand (Siam), Korea, Japan, and the Philippine Islands have been greatly afflicted by it, and it is more or less prevalent in India and in Africa. That it is not confined to tropical regions is shown by its occurrence in recent times in Newfoundland, Labrador, and Norway. In 1872 there entered the Japanese navy a young medical officer named Takaki, who noticed the great havoc wrought by beriberi and determined to find the cause and a remedy if it were possible. For the sake of more knowledge he went in 1875 to England and entered St. Thomas's Hospital Medical School, where he remained five years. Upon his return he was made Director of the Tokyo Naval Hospital, and began to study everything that might throw any light on the cause of this scourge. He finally came to the conclusion that the disease was of dietary origin, and having been made Director-General of the Medical Department of the Navy, he succeeded in obtaining permission from the Japanese Admiralty to make a number of experiments in the service "upon a scale of great magnitude."¹

On December 19, 1882, the "Riujo," a training ship bearing 276 men, sailed from Yeddo Bay to New Zealand, South America, and Hawaii, and then back to Japan, a voyage lasting 272 days. There were 169 cases of beriberi and 25 deaths before reaching Honolulu.

¹ Takaki, K. "The Preservation of Health amongst the Personnel of the Japanese Navy and Army." *Lancet*, No. I, page 1369 (1906).

Then Takaki sent the "Tsukaba," another training ship, with a similar crew over the same course, but with a better ration as shown by the following table:

Food	Diet on the "Riujo"	Diet on the "Tsukaba"
	Weight, Ounces	Weight, Ounces
Rice	27.78	32.16
Vegetables	9.56	12.41
Fish	4.85	6.56
Meat	2.18	8.02
Other food not specified	...	Milk and tea added
Total weight of ration	50.37	78.38

The "Tsukaba" was gone 287 days, but only 14 men had beriberi, and these did not eat their full allowance of the new ration. As a result of this experiment, in 1885 Takaki secured the adoption of a new dietary for the entire Japanese navy, in which the total food was further increased, the rice decreased, wheat and bread added, the vegetables increased, and the milk allowance made $1\frac{1}{4}$ pints daily.

A few years later, in the Dutch East Indies, Dr. C. Eijkman, director of the hygienic laboratory at Batavia, Java, noted that certain fowls manifested symptoms curiously like beriberi and began an investigation of the cause. In 1897 he reported that the disease of the fowls (polyneuritis) was the same as beriberi in man and was due to the lack of some substance essential to normal nutrition not present in polished rice but obtainable from the rice polishings. Eijkman induced the government to order an examination into the influence of rice feeding on human beriberi in the prisons of Java, by which it was shown that only one in 10,000 living on unpolished rice acquired the disease, while 3,900 in 10,000 living on polished rice developed it. The work of Eijkman was extended by Grijns, who showed that the antineuritic substance which Eijkman had found in the outer layers and embryo of the rice kernel also occurred in certain beans (*Phaseolus radiatus*). Their efficacy was put to the test by the sanitary inspector of Java, who for nine months gave part of the inmates of a certain lunatic asylum white rice only and another group rice plus about 5 ounces of the beans daily, and found that no one who ate the beans had beriberi, while over one-third of those who did not eat them developed the disease.

Such experiences greatly stimulated effort to discover the nature of this antineuritic substance. Several independent investigators within less than a year (December 1911–July 1912) succeeded almost simultaneously in separating from rice bran and from yeast a substance which would cure the disease when induced in pigeons by feeding polished rice. Of these, Casimir Funk was the first to announce publicly that he had been able to cure, in a few hours, pigeons paralyzed with polyneuritis, by a few milligrams of the crystals which he had prepared from the rice bran (December 1911). He suggested for this substance the name *beriberi vitamine*.

While Eijkman was investigating the antineuritic properties of rice polishings, Hopkins in England was seeking the reason why a very small portion of milk added to a diet of purified proteins, fats, carbohydrates, and mineral salts made the difference between nutritional success and disaster. He was able to show that in milk and certain vegetables there was something soluble in water and also in alcohol which, when added to the ration of purified foodstuffs, enabled young rats to grow.

Also, in New Haven, Osborne and Mendel were finding repeated instances of the superiority of their “protein-free milk” over a mixture of pure lactose plus pure mineral salts added to their basal diet, which led them to realize that they were dealing with some specific water-soluble growth-promoting substance.

This was also just about the time that Hart, Humphrey, Steenbock, and McCollum published the first report of their investigations in feeding cattle on rations from a single plant source and began the search for an explanation of the differences in the nutritive value of the ration prepared from the corn plant and that from the wheat plant. McCollum and Davis found that the wheat kernel, supplemented with purified casein, a mixture of mineral salts, and butter fat, provided a diet satisfactory for the growth of the young to maturity, the maintenance of the adult, and the production of vigorous offspring. But no such success attended the application of the same procedure to polished rice. The animals failed to grow and developed polyneuritis. They then tried replacing part of the rice by milk sugar, with the result that the animals began to grow as soon as it constituted 5 per cent of the ration. If, however, they used highly purified milk sugar, there was no growth. Thinking that something must have been left behind in the water from which the milk

sugar had crystallized out, they evaporated this on the food mixture and the ration so reinforced was able to sustain growth. In 1915 this new growth-promoting food factor was called by McCollum "water-soluble B." He found that pigeons could be cured of polyneuritis by adding to polished rice the same preparation which had been found to induce growth in rats and concluded that a single substance possessed both antineuritic and growth-promoting properties. It soon came to be known as vitamin B. But as the quantitative study of its presence in foods was promptly pursued in many laboratories, various unaccountable irregularities in the results suggested that there must be more than one vitamin. Thus yeast when heated under pressure (autoclaved) lost its power to cure polyneuritis in a pigeon, yet it could still stimulate growth in a rat. It took a number of years for the full significance of such conflicting results to be reconciled, but by 1928 it was finally established beyond doubt that what had been thought a single vitamin was in reality a mixture containing an antineuritic substance, at that time called vitamin B or B₁, and now known as thiamine, and another growth-promoting factor, which received at that time the name of vitamin G or B₂ and has now been given the name riboflavin.

Crystallization and Chemical Identification of Thiamine

Funk in 1911 prepared a few crystals of what he called the "beriberi vitamine" but could not find a way to get sufficient material for further study. It was not until 1926, in the laboratory in Java where Eijkman had made his pioneer studies, that pure crystals, prepared by Jansen and Donath, were used to cure human beriberi. Within a very few years workers in Japan, Germany, and England were also able to obtain crystals which by all biological tests seemed to be identical.

The next step was their chemical analysis, and here, too, there was soon agreement that the vitamin contained carbon, hydrogen, oxygen, nitrogen, and sulfur, but results of computing the proportions of each element differed slightly. Progress was difficult because of the small amount of material available for analysis. Among those actively seeking to solve the problem of chemical structure was R. R. Williams, Chemical Director of the Bell Telephone Laboratories, who made his avocation research upon vitamin B. In the Philippines he had seen beriberi at first hand and returning to this country,

labored for nearly 24 years in research which finally led to the development of a method by which he could extract as much as 5 grams of pure crystals from a ton of rice polishings. With sufficient material and able assistance from the Carnegie Institution of Wash-

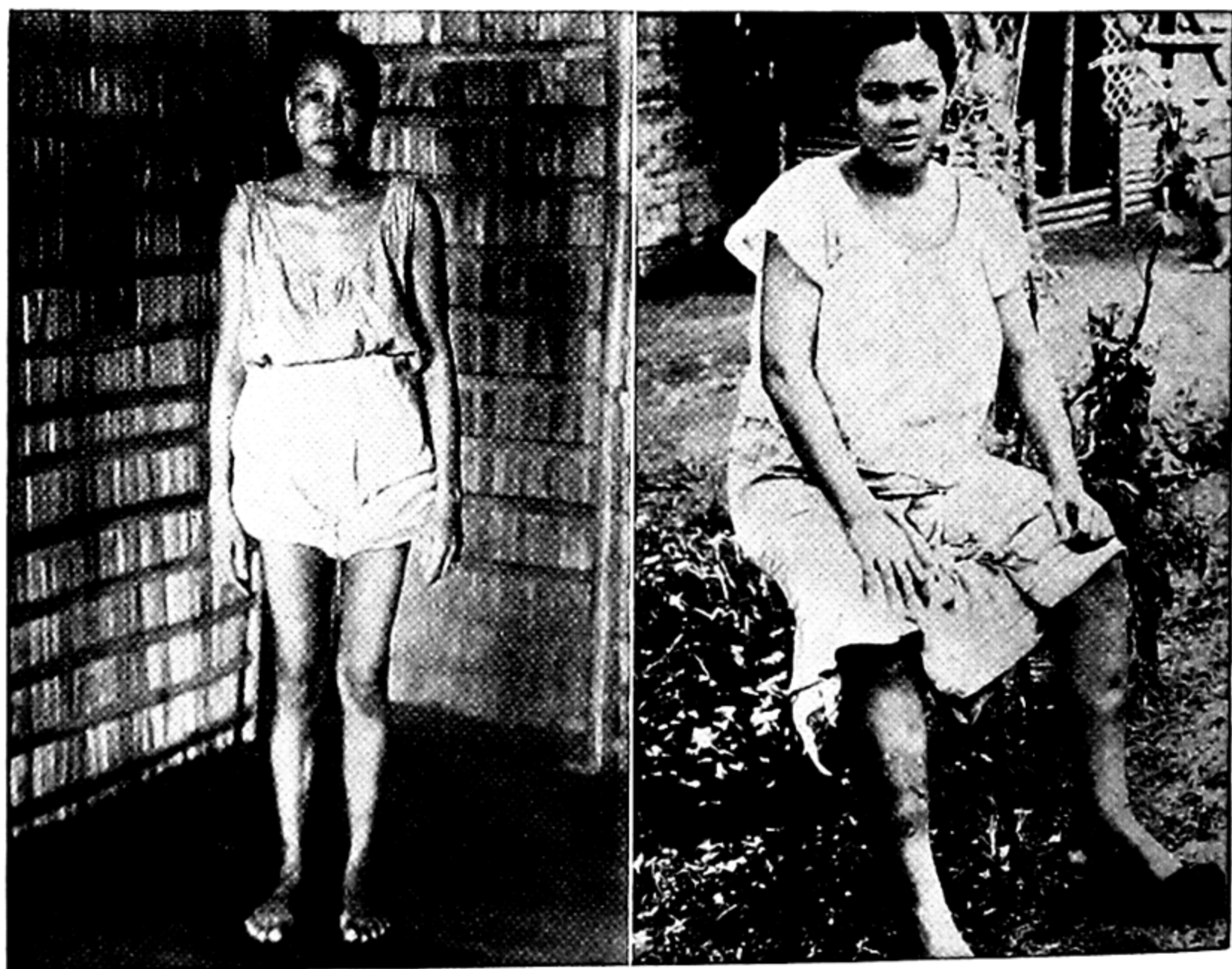


(Courtesy of Merck and Co., Inc.)
Fig. 65. Crystals of Thiamine

ington, which supplied funds; from the Laboratory of Physiological Chemistry at Teachers College, Columbia University, where much of the work was done; from the Department of Biochemistry of the College of Physicians and Surgeons of Columbia University the problem of chemical structure was attacked with fresh zeal. A misfortune of earlier years was turned to good account, for sulfur dioxide, which destroyed the vitamin where it was used as a preservative for rice polish extracts, proved a tool for neatly splitting the molecule into two pieces. One of the pieces contained the sulfur, and this was found to be held in a chemical structure not hitherto found in nature, so that Williams remarked, "It is not difficult to

imagine that its discovery may ultimately prove more important in biochemistry than the structure of the vitamin itself.”² Only the development of new technics in chemistry made possible the many tests which were necessary for the full identification of both parts of the molecule and of the way in which they are held together.

The next objective was to find a way to synthesize the vitamin. This would not only afford final proof that the structural formula was right but would open the way to commercial manufacture of the



A

B

(Courtesy of The Institute of Nutrition, Manila)

Fig. 66. Two Types of Beriberi

A. This thirty-four-year-old Filipino mother is suffering from “dry” beriberi although she shows little outward sign of the disease. Note the leanness of the legs. Of her ten pregnancies three resulted in spontaneous abortions; five infants died before reaching three months of age. Only two survive, one an infant, the other nine years of age.

B. This twenty-two-year-old expectant Filipino mother is suffering from “wet” beriberi. Death from beriberi faces her unborn child. Her hands and feet are already numb and her legs swollen. The pits on her shins have been produced by finger pressure and are characteristic of this type of beriberi.

² Williams, R. R. “The Vitamin B Adventure.” *American Journal of Public Health*, Vol. 25, page 481 (1935).

vitamin and afford material for further study of the functions of the vitamin in nutrition. Nearly two years more were spent in this phase of the investigation, and in 1936 the building of the molecule in the laboratory, step by step, was finally accomplished.³

When the molecular structure had thus been established, the compound was given the name "thiamin." Later the spelling was changed to "thiamine" which is now the official name of this vitamin. The form of the synthetic vitamin commonly found on the market is thiamine hydrochloride, a compound of thiamine and hydrochloric acid which is more stable than thiamine itself.

Prevention and Cure of Beriberi and Polyneuritis

Beriberi is a disease characterized by changes in the nervous system which have far-reaching effects throughout the whole body. In human beings it has two fairly well-defined forms: dry beriberi (Fig. 66A), in which there is great muscular wasting, loss of sensation in the skin, paralysis beginning in the legs and finally extending to the upper portions of the body; and wet beriberi (Fig. 66B), in which there is a marked edema in the arms, legs (Fig. 67), and finally the trunk, with great enlargement of the heart, so that death from heart failure is common. The disease develops on diets low but not completely lacking in thiamine. They are usually poor in other respects, so that the uniformity of symptoms observed in laboratory animals does not occur. A great deficiency of thiamine produces the disease rapidly, but a less severe shortage may delay development of acute symptoms for a long time, and slight deficiency gives rise only to subacute



(Courtesy of Dr. T. D. Spies)

Fig. 67. A Case of Pitting Edema Resulting from Thiamine Deficiency
Note the pitting caused by pressing with the fingers.

³ Williams, R. R., and Cline, J. K. "Synthesis of Vitamin B₁." *Journal of the American Chemical Society*, Vol. 58, page 1504 (1936).

symptoms which will be discussed in later pages in connection with appetite and digestion. Beriberi often follows prolonged fevers, especially malaria. In such a situation bad gastrointestinal conditions and an increased energy expenditure tend to accentuate the effect of a diet deficient in thiamine.

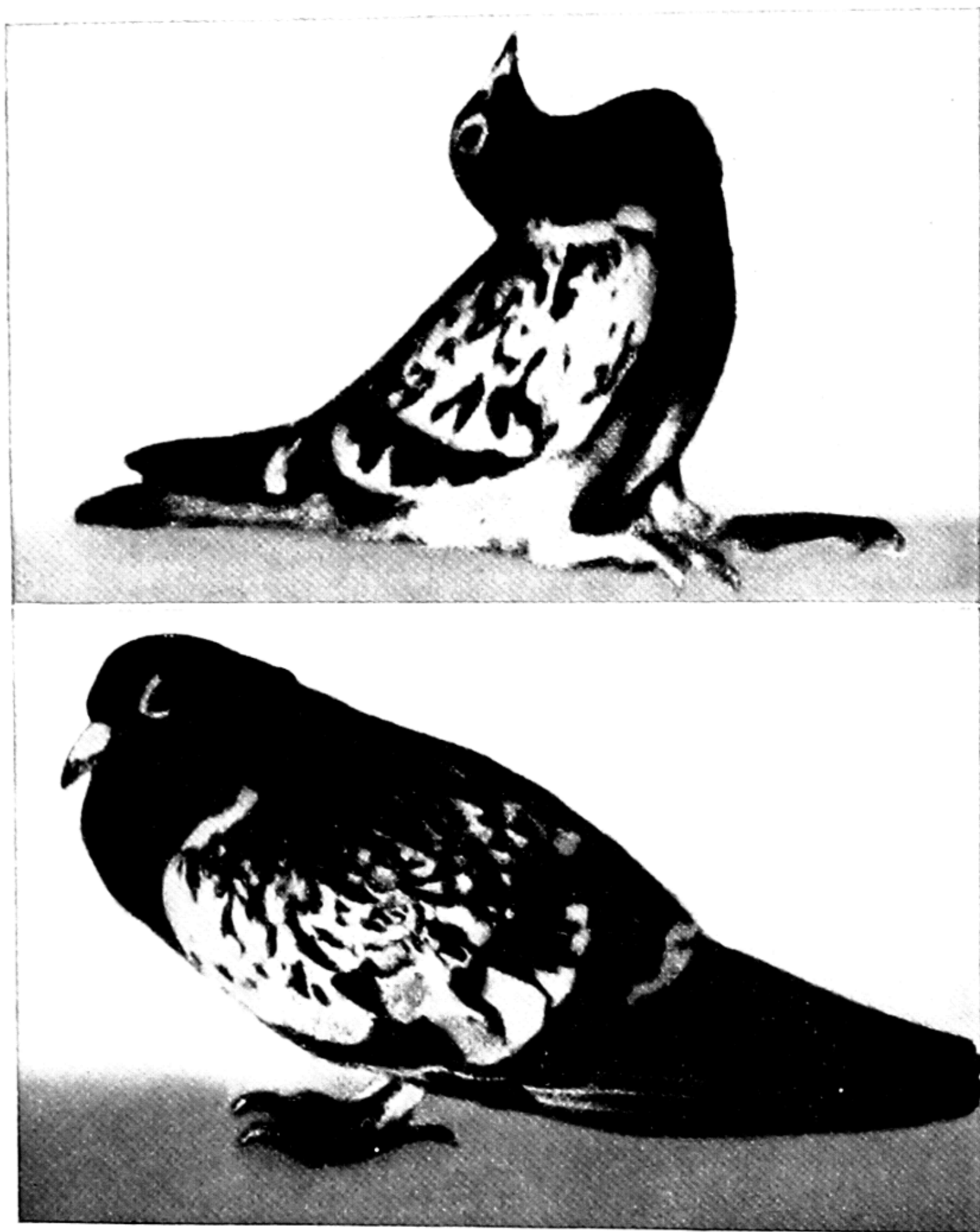
In pigeons deprivation of thiamine results in polyneuritic symptoms in from three to five weeks. Sometimes there is weakness and general paralysis; sometimes there develops the typical head retraction shown in Fig. 68. In dogs there is a tendency for paralysis to manifest itself in the hind legs.

In young rats a characteristic distortion of the spinal column is one of the first symptoms of the nerve involvement which is always a result of thiamine deficiency (Fig. 69).

In human beings it is now realized that thiamine plays an important role in the maintenance of a functionally normal nervous system and that a deficiency of thiamine may be responsible for various forms of nerve disturbance. The ordinary American dietary in which too much prominence was given to artificially refined foods tended, until the "enrichment" of white bread and flour was enforced, to be low in thiamine. If there is any failure of absorption because of unfavorable conditions in the alimentary tract or because of infection, a real deficiency may exist where it is not suspected. A study of 100 cases of human neuritis by Vorhaus and Williams directed attention to the value of thiamine for the well-being of the nervous system. Many of these cases were of long duration and unresponsive to other forms of treatment, but only 10 per cent failed to improve when given 10 milligrams of pure thiamine daily, and 44 per cent were entirely cured.⁴

The cause of these symptoms in the peripheral nerves was first sought by histological examination of the nerve fibers, but no changes in their structure were found which could account for the severity of the symptoms or the speed with which they could be cured. It is a spectacular effect which one observes when a rat, moribund from inanition and polyneuritis and unwilling to eat, can be revived within two or three hours if given massive doses of thiamine by mouth with a medicine dropper, and still more dramatic if the vitamin is injected directly into the blood stream, because the re-

⁴ Vorhaus, M. G., and Williams, R. R. "Studies on Crystalline Vitamin B." *Journal of the American Medical Association*, Vol. 105, page 1580 (1935).



(Courtesy of Dr. Casimir Funk and the British Medical Journal)

Fig. 68. The upper pigeon, raised on a diet lacking thiamine, shows the typical head retraction of polyneuritic birds. The lower pigeon was raised on the same diet plus rice polishings as source of thiamine and is normal in every way.

covery may take no more than a quarter or half an hour. It was the successful use of this latter method of curing polyneuritis that aided Williams materially in developing his method of isolating thiamine from rice bran, since at each step of the work tests could be made to see whether the vitamin was in a solution or in the material filtered out.



(Courtesy of The Upjohn Company)

Fig. 69. Polyneuritis in the Rat

The thiamine-deficient rat (upper) shows the typical arched back and hyper-extended hind legs. Such rats show spastic gait, turn awkwardly, lose balance and sense of direction. The same rat (lower) eight hours after administration of thiamine has normal use of its hind legs and has regained balance.

Such changes are too speedy to involve regeneration of tissue. Hence the solution of the problem had to be sought by study of function. In 1929, Peters of the University of Oxford found that pigeons dying of polyneuritis have an increased amount of lactic acid peculiarly localized in the lower parts of the brain, and not in the cerebellum. Upon further study, it was discovered that when a portion of tissue from the brain of a polyneuritic pigeon was put into a suitable type of respiration chamber and supplied with glucose for oxidation, it was unable to oxidize it as fast as the brain tissue from a normal bird, as shown by the rate of oxygen consumption. Proof that shortage of thiamine was responsible was furnished by injecting it under the skull into the part of the brain where the lactic acid had accumulated. In an hour the acute nervous symptoms would disappear and the power of the brain tissue to use oxygen for carbohydrate combustion would be restored. Also the excess lactic acid would disappear. This not only solved the problem of the cause of polyneuritis but also proved that thiamine is a regulator of carbohydrate metabolism. Funk called attention in 1914 to the fact that polyneuritis developed more quickly if the animals were given diets very rich in carbohydrate. Later, various workers reported that thiamine deficiency brings about a drop in carbohydrate tolerance even before nervous disturbances appear. Also it was found that in human beriberi there is an increase in the blood of intermediate products of carbohydrate metabolism which disappear on administration of thiamine.

Explanation of these changes is found in the work of various

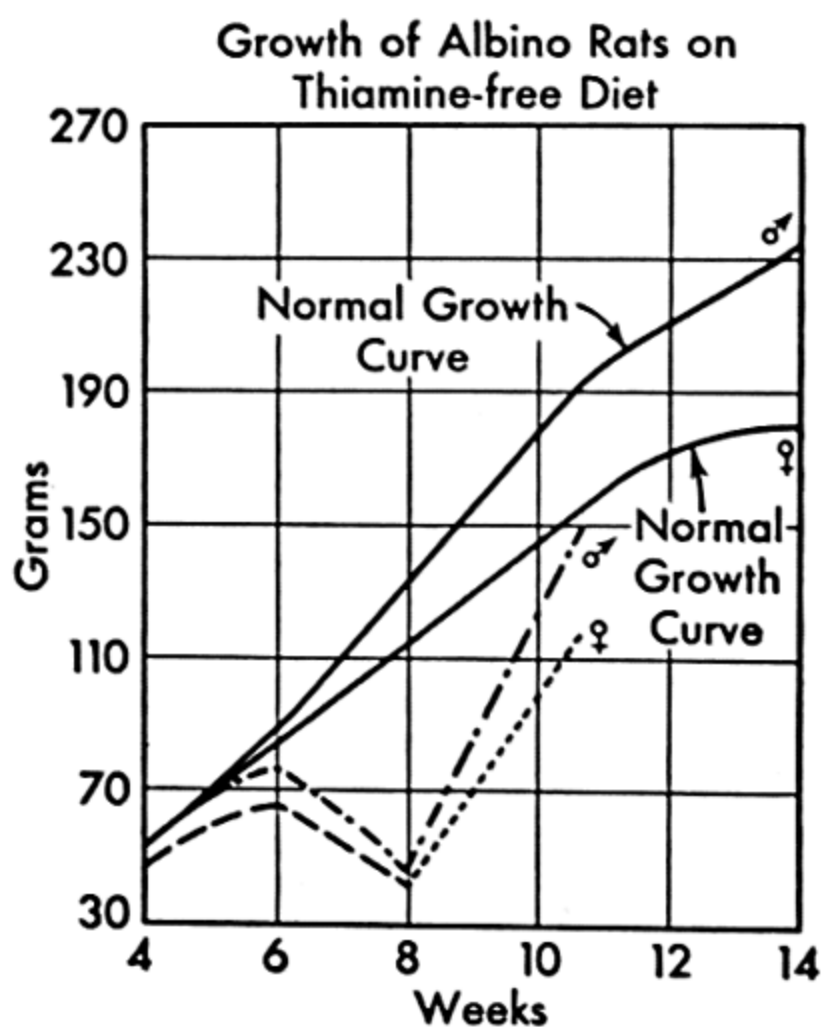
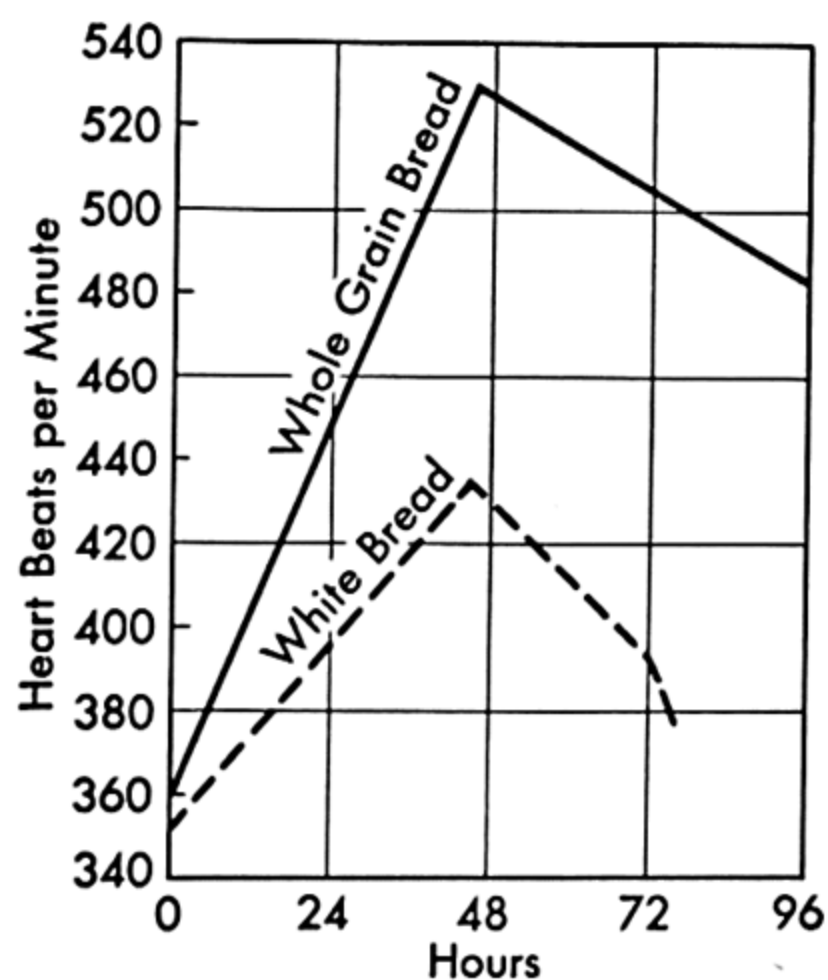


Fig. 70. Growth curves of rats on a thiamine-free diet compared with those of normal rats of the same age. When thiamine in the form of wheat germ extract was added to the diet the weight was tripled in less than three weeks.

investigators, who have established the fact that thiamine forms a compound with phosphoric acid (thiamine pyrophosphate or cocarboxylase) which acts as a catalytic agent in bringing about the normal metabolism of carbohydrate in cells in all parts of the body.

According to Harris of the University of Cambridge, pyruvic acid (another product of incomplete combustion of carbohydrate which accumulates in the blood when the diet is deficient in thiamine) poisons the muscles of the heart and slows its beat till that of a polyneuritic rat will be only about half as fast as that of a normal animal. The response is so prompt and so nicely regulated by the amount of thiamine administered that Harris and his associates used it as a test for the thiamine content of foods. Rats deprived of the vitamin are tested from day to day after they begin to decline in



(After Birch and Harris)

Fig. 71. The effect of feeding a single portion of whole grain bread, rich in thiamine, on the rate of the heart beat of a rat after the rate had been retarded by deprivation of the vitamin, compared with the effect of a single portion of white bread, containing very little thiamine.

weight by making tracings of the heart beat, which is measured electrically, being too fast to count. When the rate falls from the normal level of about 500 beats per minute to about 350, a portion of the food to be tested is given (Fig. 71), and records of the heart rate made at intervals until the maximum effect of the food tested has been obtained, followed by a gradual decline, showing the difference in effect of a gram of whole grain bread, rich in thiamine, and one of un-enriched white bread which has only a very small amount derived from the yeast.

The spectacular cure effected in a few minutes or even a few hours does not restore a very polyneuritic animal to full health. A rat may have been left in the

evening eating the food and apparently well, and yet the next morning it may be found dead. The changes in the nervous tissue are not healed as soon as combustion of pyruvic acid is again possible, and liberal

doses over a considerable time must be given to restore the tissues to normal condition.

In humans, the following symptoms have been reported as associated with the "beriberi heart": enlarged heart, dependent edema of the legs, elevated venous pressure, peripheral neuritis, and other manifestations. The dietary history and possible relationship to alcoholism should be investigated. The response to treatment with thiamine will depend to a large extent on the duration and severity of the condition. In any case a physician should be consulted, since other heart conditions may show similar symptoms.

That the mortality rate of a large population group can be reduced by a slight change in the nutritive quality of the diet was convincingly demonstrated under controlled experimental conditions in the Province of Bataan in the Philippines. This tremendous undertaking was directed by R. R. Williams, who might well be called "the father of the enrichment program." By adding a premix containing thiamine, niacin, and iron to all of the polished rice produced in one area with a population of 63,000 people, thus insuring almost exclusive use of this enriched rice as the basic source of calories, the mortality rate due to beriberi was reduced from 263 per 100,000 in 1947-48 to 28 per 100,000 in 1949-50. The rate in 1949-50 is only a small fraction of the lowest annual rate previously recorded in Bataan. The incidence of beriberi in the seven cities in the experimental area was reduced by approximately 90 per cent. The comparison of the mortality rate in the experimental area with that of an adjacent control area having a population of 29,000 is shown in Fig. 72. The mortality rate remained high in the control zone until enriched rice began to creep in. By April 1, 1950, the death rate from beriberi in all of Bataan reached zero.

The conquering of beriberi in the Philippines is the result of the persistent and continuous efforts of R. R. Williams in following an idea which came to him in the Philippines in 1910 when he was first given a half-liter bottle of rice polish extract by Colonel Vedder to be analyzed for all components, knowing that it contained the vital substance which would cure beriberi. Twenty-six years of vigorous effort brought the synthesis of thiamine in 1936, as described earlier in this chapter, and four decades of work resulted in the production of thiamine on a large scale and the final conquest of beriberi.

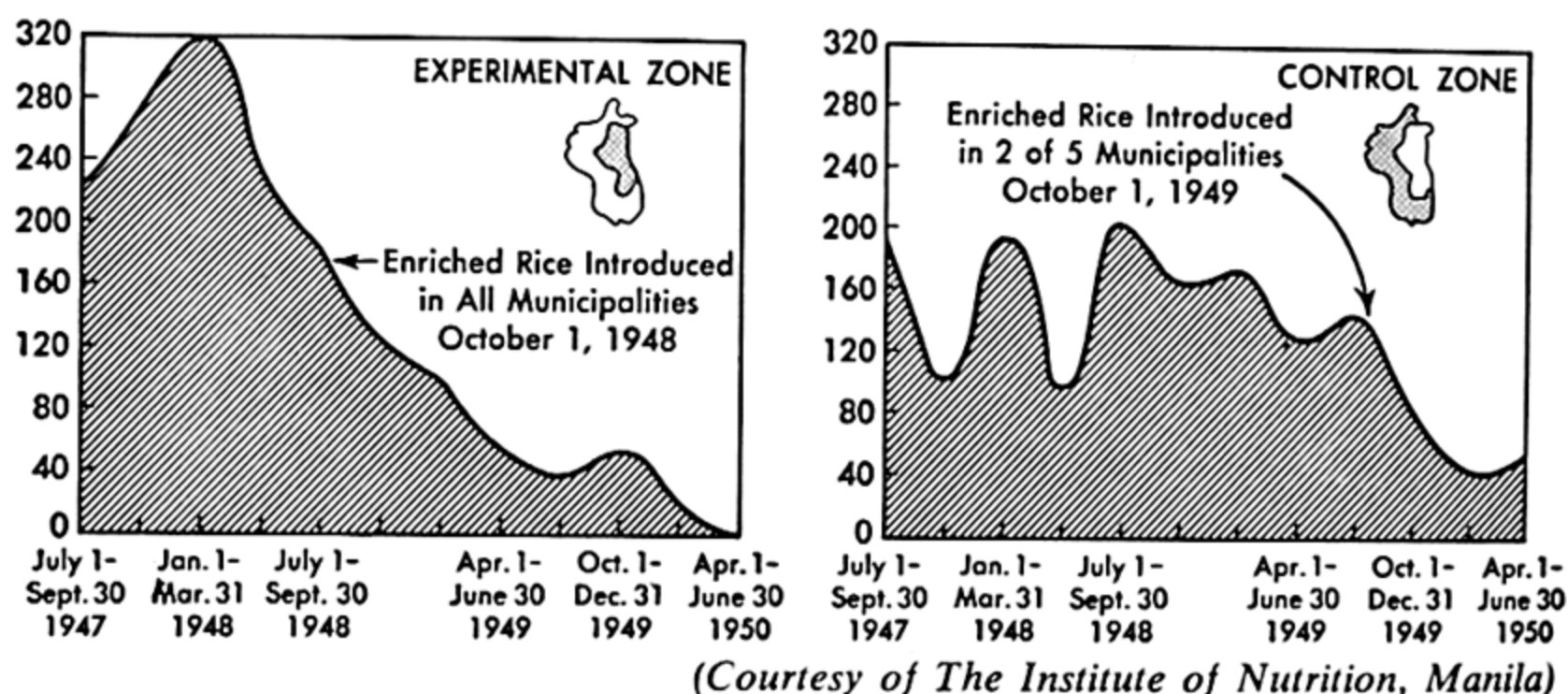


Fig. 72. Reduction in Beriberi Death Rate per 100,000 Population in Bataan

These graphs show the effects of the enrichment of rice on the mortality rate in Bataan from 1947 to 1950 in an experimental and a control zone.

Maintenance of Appetite

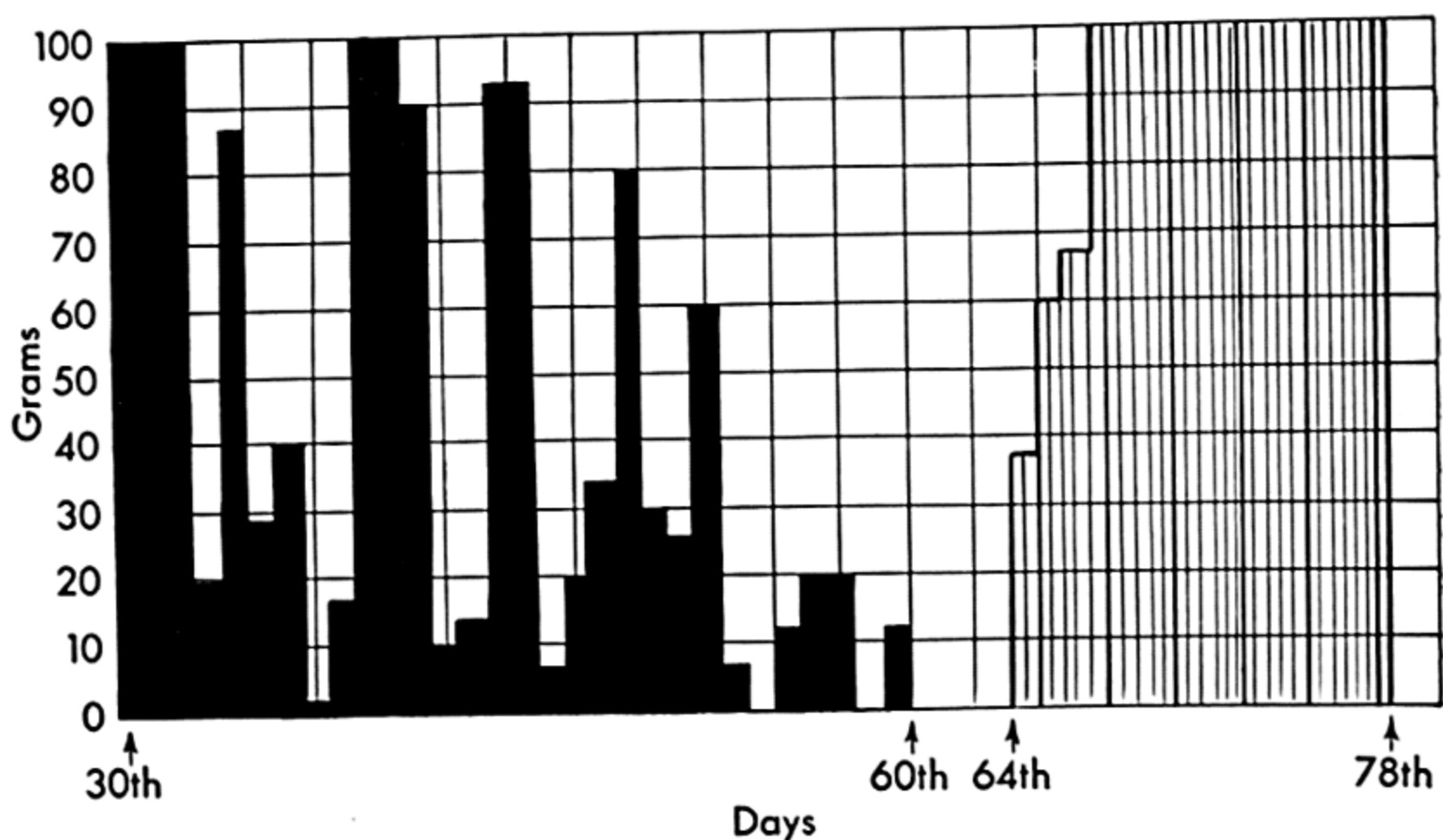
The food intake of young rats deprived of thiamine drops shortly after they are placed on the deficient diet, demonstrating clearly the importance of thiamine for the maintenance of a normal appetite. The dog's appetite also is sensitive to lack of thiamine. Cowgill, Rosenberg, and Rogoff⁵ found that an animal deprived of thiamine would for a time consume all the food offered in a very few minutes, normal dog fashion, then become less interested, and finally lose entirely the impulse to eat. At this point a dose of thiamine would promptly bring back the former keen appetite. Food refused in the morning would be ravenously consumed later in the day. No such effect followed administration of beef extract, showing that the taste of the food was not the explanation of the difference. Further proof that thiamine is the specific factor involved in loss of appetite is afforded by the fact that the urge to eat can be restored by introducing the vitamin directly into the blood stream instead of giving it by mouth.

There are many cases on record in which the appetites of presumably well-fed infants have been improved by an increase in the supply

⁵ Cowgill, G. R., Rosenberg, H. A., and Rogoff, J. "Studies in the Physiology of Vitamins. XV. Some Observations of the Effect of Administration of the Antineuritic and Heat Stable Factors on the Anorexia Characteristic of the Lack of the Vitamin B Complex." *American Journal of Physiology*, Vol. 96, page 372 (1931).

Thiamine

of thiamine in the diet. The possibility of thiamine deficiency in infants was suggested to Dr. Hoobler of Detroit after observation of infantile beriberi on a visit to the tropics. "It seemed to me," he



(After Dr. G. R. Cowgill)

Fig. 73. Food intake of a dog kept on a thiamine-free diet for 60 days. On the sixtieth day it was given 10 grams of beef extract, with no improvement in appetite. On the sixty-fourth day one 5-gram dose of a thiamine concentrate was given. There was immediate improvement in appetite, which continued through the seventy-eighth day.

wrote upon his return, "that many of the symptoms of mild and incipient cases of this disorder had their counterpart in the children's wards of hospitals in this country." ⁶ The most common symptom was lack of appetite. Infants suspected of receiving an insufficient amount of thiamine were given about one-half teaspoonful daily of a brewer's yeast concentrate. Those who were refusing portions of their food gradually increased their food intake when the yeast concentrate was added. There was also a certain type of stiffness in arms, legs, and neck which quickly subsided on feeding thiamine. One infant, given one-half teaspoonful of brewer's yeast concentrate daily, had changed in two weeks "from a thin, pale, spastic, restless, whining infant, refusing part of its formula, to a happy, rosy-cheeked, smiling baby whose appetite seemed never to be completely satisfied and whose gain in weight was remarkable." Hoobler recommends that "just as

⁶ Hoobler, B. R. "Symptomatology of Vitamin B Deficiency in Infants." *Journal of the American Medical Association*, Vol. 91, page 307 (1928).

regularly as orange juice and cod liver oil are prescribed one should also prescribe a substance rich in thiamine for the infant dietary." Today, many babies with poor appetites have responded to the addition of thiamine along with an all-round good diet.

The effect of thiamine deficiency upon appetite is so much more specific than that of any other nutritional deficiency that it is commonly stated that one of the functions of thiamine is that of stimulating appetite. It would, perhaps, be more accurate to say that thiamine acts as a regulator or stabilizer of appetite. If appetite has been lost because of too low an intake of the vitamin, recovery of appetite will be promoted by an increased intake but probably only to a normal level. If in a given case of poor appetite administration of extra thiamine brings about improvement, the conclusion would seem justified that the poor appetite had been due to insufficient intake of the vitamin.

Maintenance of Good Digestion

When pigeons deprived of thiamine are forcibly fed, the food remains in their crops and does not digest. When dogs begin to show signs of paralysis after a period of thiamine deficiency, they frequently vomit and have a foul breath. McCarrison⁷ long ago called attention to the prevalence of gastrointestinal disorders among civilized peoples in contrast to the freedom of certain more primitive races from such disturbances and attributed the difference to the diet. "It is the gastrointestinal tract, the functions of digestion, absorption and assimilation that are among the first to fail in consequence of faulty food. These are the signs that our ship is running upon the rocks and, as good pilots, we must be aware of them. I often think that we are apt to assume more readily the office of salvors of wrecks than of pilots whose function it is to prevent them." McCarrison took 36 wild monkeys, captured in the jungles of Madras, used 12 as controls on a normal diet, and put the rest on experimental diets. When thiamine was deficient there was great disturbance of the motor functions of the intestinal tract and impairment of the mucous lining which reduced its ability to resist the inroads of bacteria and protect the body against infection.

In Cowgill's dogs, even before lack of appetite manifested itself

⁷ McCarrison, Robert. "Faulty Food in Relation to Gastro-intestinal Disorders." *Journal of the American Medical Association*, Vol. 78, page 1 (1922).

at all, stomach contractions were less vigorous, and when appetite failed completely, the stomach was practically inert. On receiving thiamine, gastric activity improved along with the recovery of appetite (see the diagram on page 259), but did not attain full vigor for a week.

Rats show the same depression of digestive activity, when observed by means of the X-ray, not only in the stomach but also in the intestines, the emptying time of the stomach and small intestines being half again as long, and that of the large intestine about twice as long in thiamine-deficient animals as in normal ones. It has also been found that a food pellet impregnated with charcoal will pass through the alimentary tract of normal animals in three to seven days, but that in those deprived of thiamine it takes as long as twenty-four days. A third type of evidence is obtained from injecting fluid into the colons of rats on diets lacking thiamine and comparing the volume with what could be held by normal rats, a large majority of the animals deprived of the vitamin having colons so relaxed that they could receive twice the amount possible for normal ones. A study of the amount of bran necessary for normal elimination in a rat showed that when the bran was deprived of its thiamine twice as much was necessary as when the natural product was fed.

Similar observations were made on human beings by Fletcher and



(Courtesy of Col. R. McCarrison)

Fig. 74. A monkey fed for 55 days on a diet lacking thiamine. The wrist is paralyzed and shows a characteristic "wrist drop." It is trying to capture body fleas and seems unaware that the tip of the first finger and thumb do not touch each other. One leg also tends to give way under the weight of its body so that the erect position is held with difficulty.

Graham at the University of Toronto Hospital. Forty patients with chronic arthritis (a disease in which digestion is often impaired), who had very greatly relaxed and sluggish intestinal tracts, showed remarkable improvement when large doses of thiamine in the form of yeast or wheat germ were administered. Vorhaus and Williams reported eight cases specially selected for treatment because of poor tonus of the alimentary tract, with the failure of appetite and sluggish elimination which are almost inevitable accompaniments of such a state. They were given liberal doses of pure thiamine and in all normal appetite was restored and weakness disappeared. Six of the eight were completely cured of constipation and the remaining two showed definite improvement.

All of these studies tend to confirm McCarrison's view that many people who do not call themselves sick, but who take various remedies for "sour stomach," "morning mouth," headache, or constipation, might find their digestion improved by increasing their intake of thiamine. Children need a high thiamine intake for growth but grown people need liberal supplies also for the health of the alimentary tract. As they advance in years and cut down their calorie intake to adjust to lowered physical activity, they need to see to it that their supply of thiamine is still kept at the optimum.

The Promotion of Growth

The failure of appetite and disturbance of digestion which quickly result from complete deprivation of thiamine inevitably affect growth. If a young rat is weaned from a mother on an adequate diet and then is given in its ration everything needed for growth except thiamine, it will continue to grow only until the small reserve of the vitamin in its body is exhausted, and then it will quickly decline in weight and die. From lack of nourishment the animal will become greatly emaciated and will not live long enough to show very clearly the most characteristic symptom of shortage, polyneuritis. There will, however, be some evidence of this in the distortion of the spinal column and consequent humping of the back which may be seen in Fig. 69.

A single dose of thiamine concentrate will produce signs of returning health in a very few hours. The animal becomes interested in food and drink, the nervous symptoms are allayed, and the rapidity with which growth is resumed is truly amazing. The growth curves

for the animals portrayed in Fig. 69 are shown in Fig. 70. The speedy decline in weight of the animal without thiamine, and its recovery when on the verge of death, are typical of experience with hundreds of animals under similar circumstances.

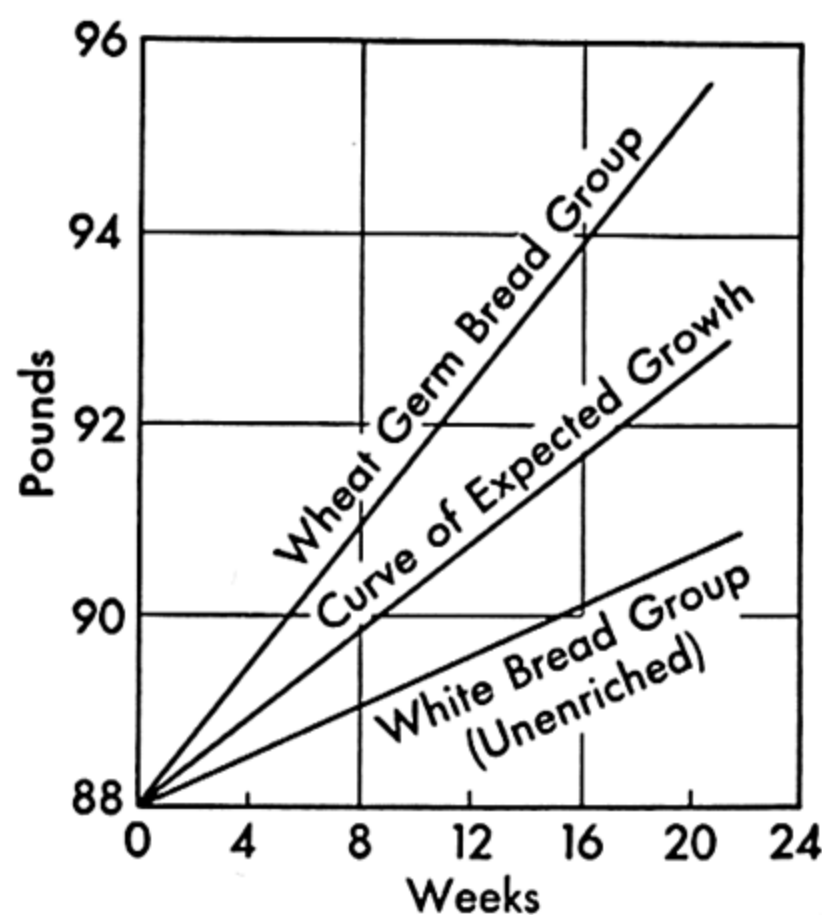
There have been many observations of the importance of thiamine for the growth of human infants. Dennett, a distinguished New York pediatrician, observed a period between the ages of five and ten months when many artificially fed babies given orange juice and cod liver oil and otherwise fed according to the accepted standards at that time grew poorly or ceased to gain, became fretful, flabby, and pale, and either lost their appetites or failed to assimilate their food properly. To see whether lack of thiamine was the cause of the trouble, he fed a large number of infants a preparation of the vitamin made from wheat germ as an addition to a modified milk formula. The babies that were adjudged well at the start, 129 in number, showed in the course of a few months a surprising freedom from disturbances of appetite and their gains in weight were considerably above the average for their age, while the babies that were already showing symptoms of some deficiency, 29 in number, "did exceedingly well," had good appetites by the end of the first month and at the end of five months had firm muscles and good color, had made up their lost weight, and compared favorably with normal infants of their age.

An interesting report is that of Clements⁸ who states that whereas infantile beriberi is rare in Australia cases of partial thiamine deficiency due to an insufficient amount in the mother's milk are not uncommon. In 12 of 150 infants breast-fed to the age of six months he found evidence of such partial deficiency. When the nursing mothers whose milk showed insufficiency of thiamine were given 0.45 milligram per day of the synthetic vitamin, the infants showed a prompt increase in rate of growth and vomiting and constipation ceased.

To see whether older children on a more varied diet would be benefited by more thiamine, Morgan and Barry of the University of California fed a group of undernourished school children between eleven and thirteen years of age as a part of their school lunch, two rolls daily, made with 50 per cent of white flour and 50 per cent

⁸ Clements, F. W. "Symptoms of Partial Vitamin B₁ Deficiency in Breast-fed Infants." *Medical Journal of Australia*, Vol. I, page 12 (1942).

of wheat germ, and compared their growth with that of a control group fed the same number of rolls made from white flour only. The increase in weight of the wheat-germ group was approximately



(Courtesy of Professor Agnes Fay Morgan)

Fig. 75. This chart shows the average increase in weight of a group of twelve-year-old school children receiving daily as supplementary food two wheat germ bread rolls, in comparison with a control group fed a similar amount of white unenriched bread rolls.

will be revealed during lactation, since both mother and child may develop beriberi when the mother's low supply comes to be shared with the baby.

The need of the young for thiamine is much greater per unit of body weight than that of adults. The higher the basal metabolism and the more rapid the rate of growth, the greater the requirement. Less vitamin is needed when given directly to the young; it is estimated that the lactating mother wastes over half the daily supply of thiamine in transferring it to the milk.

According to Macy of the Children's Hospital of Michigan, who has made extensive studies of the vitamin content of human milk, it is at best not a relatively rich source of thiamine. Hence the surest way to protect the young is to administer an adequate amount of the vitamin directly to them. Aside from the fact that transfer of the vitamin is poor, the growing organism needs so much more of the

three times that of the white-rolls group, and gains in height, though not so striking, were significantly greater in the wheat-germ group. These and other experiences too numerous to mention make clear not only the advantage of liberal thiamine intake for the best growth, but also the danger that poverty or carelessness may deprive children of a sufficient amount of this factor. At the same time it emphasizes the need for continued support of the enrichment program.

Reproduction and Lactation

Women who have beriberi seldom bear children. Those with a less severe restriction of thiamine may produce apparently normal babies, but the dietary deficiency

vitamin in proportion to its size than the adult that every precaution should be taken against any scarcity.

For discussion of thiamine in relation to requirement for pregnancy and lactation, see section on Requirement.

Measurement

A number of methods have been proposed for determining the thiamine value of food materials. These include the biological, chemical, and microbiological methods.

The biological method was naturally the first devised since chemical methods could not be developed until the chemical structure of thiamine was known. Hens, cocks, pigeons, and rats have been used as test animals. The method consists of comparing the growth of young rats depleted of their limited store of the vitamin and fed the food to be tested with that of the growth of animals fed known amounts of the pure vitamin. Since the development of the chemical and microbiological methods, the biological method is not commonly used. In 1931, the vitamin committee of the Health Organization of the League of Nations defined the International Unit of thiamine as 3 micrograms of the pure crystalline vitamin. Now that the synthetic thiamine hydrochloride is available, the synthetic preparation is taken as a standard and the quantity of thiamine is expressed in milligrams of thiamine rather than in International Units.

Of the several chemical methods that have been devised for determination of thiamine, that which depends upon converting the thiamine in food material into thiochrome and then measuring the fluorescence in a fluorometer has been more commonly used.

Microbiological methods have been developed based upon the fact that thiamine is essential to the growth, multiplication, or fermentative activity of certain microorganisms.

Other methods have been devised for the determination of thiamine in blood and tissues. The yeast fermentation method has been worked out to measure the activity of thiamine in the form of the coenzyme cocarboxylase since almost all of the thiamine in the blood occurs in this form. A micromethod has been devised to measure the amount of thiamine in a very small quantity of blood.

Both chemical and microbiological methods have been found satisfactory for the determination of thiamine in the urine of humans and animals.

These methods vary widely in principle and may be carried out

in different ways in different laboratories. The selection of the suitable method to be used and the interpretation of the results require the skill of the experienced chemist.

Sources

Thiamine is found in many common foods but in comparatively small amounts. Oils and fats, cassava (source of tapioca), and refined sugar do not have any thiamine. The cereal grains are generally considered our best sources, thiamine usually occurring in germ and outer layers. However, if these grains are highly refined, such as white flour or polished rice, and are not enriched with thiamine, the diets of population groups depending on them as a major source of calories will be very deficient. Before the enrichment program became effective in the United States, it was easy to have an attractive diet adequate in all other essentials but low in thiamine because most people preferred the white bread and refined cereals. The use of enriched bread and cereals along with the whole grain products has increased the total thiamine in the diet and if the calories are not too low, the average American diet is likely to be adequate but will probably not have a great surplus of this vitamin. Beriberi occurs in countries where polished rice or cassava furnish most of the calories.

Next to cereal grains, legumes are the best common source of thiamine. Peas, Lima and soybeans, both fresh and dried, are very good sources. Dried lentils, kidney, navy, and many other varieties of dried beans are good sources. The best vegetable sources of thiamine are the dark green, leafy vegetables, such as spinach, collards, dandelion greens, kale, mustard greens, and turnip greens. Cabbage, cauliflower, kohlrabi, and okra also furnish noticeable amounts. Potatoes will furnish significant amounts of thiamine in diets where they make up a fairly large proportion of the calories as is the case in many European countries.

Fruits as a rule are low in thiamine. However, oranges and grapefruit (fresh, canned, or frozen) contribute considerable thiamine when taken regularly.

Thiamine is not present in large amounts in any of the meats except pork and the glandular organs such as liver and kidney. Muscle meats except for pork are low in thiamine. Fish furnishes less thiamine than beef. In eggs the thiamine is found in the yolk.

The richest natural source of thiamine is dried brewer's yeast. Wheat germ is also an excellent source and is now available in most food markets.

Different processes used in the preparation of ready-to-eat cereals affect the thiamine values. Reports show that when cereals are heated dry so that a large surface is exposed to a high temperature, a considerable loss of thiamine occurs. In the cooking of breakfast cereals such as oatmeal or rolled wheat with moist heat at boiling temperature, the loss is insignificant. However, 50 per cent of the thiamine may be lost in the steaming and toasting to which bran is subjected to produce a crumbled breakfast food. Many cereals now have thiamine added in amounts equal to that lost in the processes of preparation. Very little thiamine is lost in the baking of whole wheat bread. When rice is parboiled, a process in which the rice is soaked in water, then boiled, dried, and milled, much of the thiamine of the whole rice is retained. The commercially processed product is known as "converted rice."

Losses of thiamine in the cooking of vegetables in water in which the water is thrown away are significant. The addition of soda to some vegetables will increase the destruction of the thiamine present.

Dehydrating appears to have little if any effect upon the thiamine content of fruits and vegetables. Sun drying of unsulfured fruits may destroy one-third to one-half of the thiamine and if sulfured, the destruction is increased to from 60 to 100 per cent.

Some foods give evidence of having a thiamine-stabilizing substance. From the above discussion it is apparent that no generally applicable estimate of thiamine losses in cooking is possible.

A few foods have been found to contain substances (probably thiaminases) which prevent the full utilization of the vitamin. Certain varieties of raw fish, clams, and shrimps ingested with meals will reduce the availability of thiamine. This can be counteracted by having generous allowances of thiamine in the diet from other foods.

Figure 76 shows portions of some common foods which have the same thiamine value. See Tables II and IV in the Appendix for the thiamine values of other foods.

Requirement

The question of what constitutes an adequate intake of thiamine was first investigated by making studies of dietaries on which adults

were maintaining good health and children were growing normally. Evidence soon began to accumulate which indicated a wide range between a minimum which would maintain health and support growth and an optimum which would insure the *best* health and rate of growth at all times. Studies were then undertaken to discover,

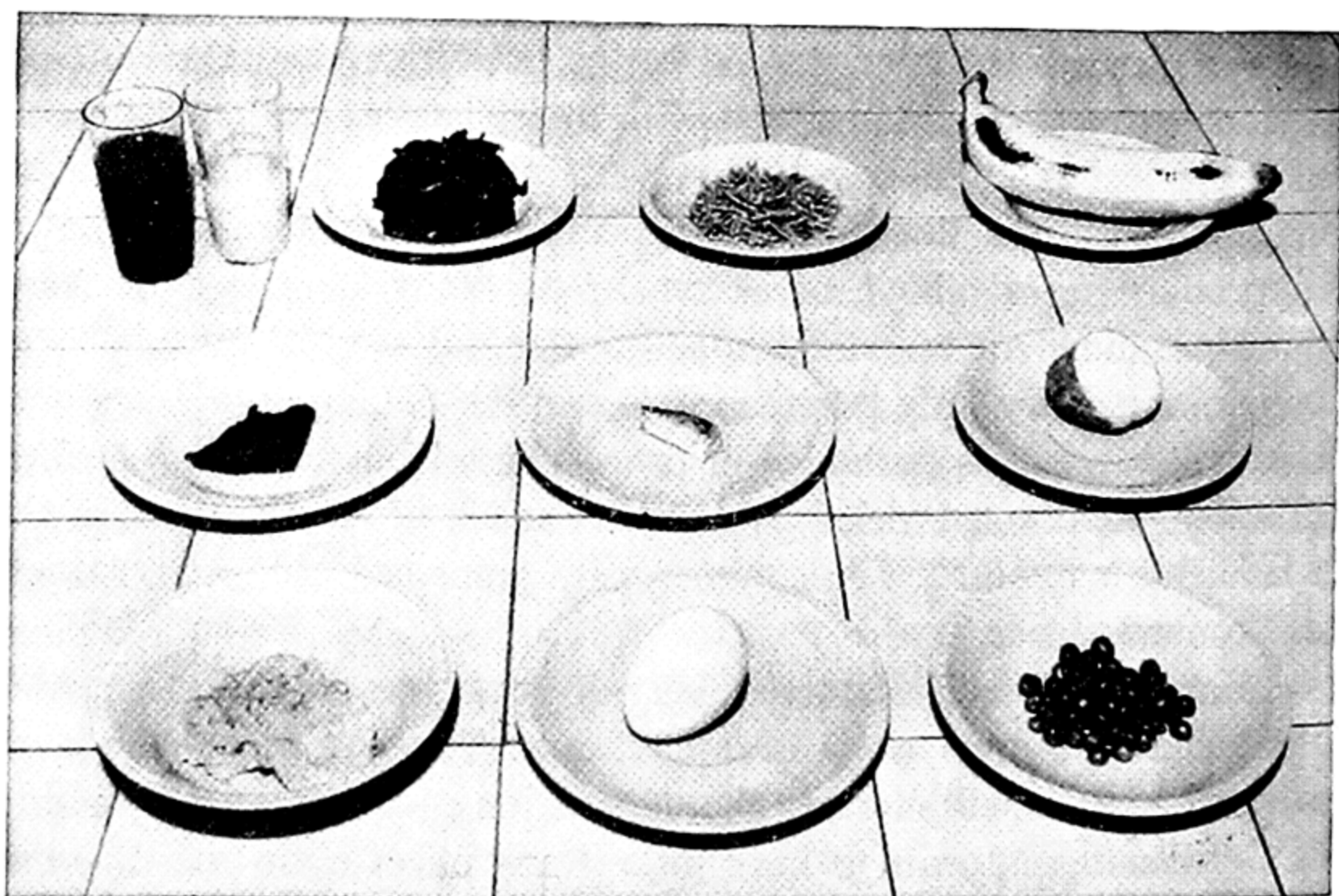


Fig. 76. Food Portions Yielding about 0.05 Milligram (One Share) of Thiamine

	<i>Grams</i>		<i>Grams</i>
Tomato juice	100	Pork, loin, roasted	6
Orange juice	63	Potato, boiled in jacket	53
Spinach, steamed	64	Oats, rolled, cooked	54
Bran (100 per cent)	14	Egg, cooked in shell	66
Banana, A.P.	188	Peas, cooked	20
Liver, fried	19		

if possible, a better basis for statements of the requirement. Cowgill and his associates in 1931 found the thiamine requirement closely related to the energy metabolism in experiments on adult dogs changed from a diet rich in thiamine to one deficient in it. When some of the dogs were forced to exercise on a treadmill signs of thiamine deficiency developed in a much shorter time than in the dogs not exercised. These findings were in line with observations of McCarrison and others that human beriberi is brought on more rapidly in patients who exert themselves physically. In Cowgill's

laboratory it was also found that loss of appetite appeared in about half the usual time in dogs on a thiamine-deficient diet when energy metabolism was increased by administering thyroid gland.

Many studies on humans to determine the most satisfactory level of thiamine intake were reported during the years 1942 through 1948. Wilder and his associates at the Mayo Foundation reported experiments on a group of eleven women placed on diets furnishing 0.22 milligram of thiamine per 1,000 calories and continued on the diet for 89 to 196 days. They became irritable, quarrelsome, depressed, uncooperative, lost manual dexterity, became inefficient in their work, and showed increasing forgetfulness. They complained of feet and hands feeling numb, suffered from headache, backache, sleeplessness, constipation, loss of appetite, nausea, and became more and more easily fatigued by very little exertion. Blood pressure, pulse rate, and basal metabolism decreased while blood sugar was often found to be abnormally high. A prompt fall in urinary excretion of thiamine was observed in every case. When the amount of thiamine in the diet was increased, these symptoms of deficiency gradually disappeared and the subjects reported feeling better. This work was followed by other studies by this same group of investigators.

Studies of subjects on low intakes were reported by Elsom and his co-workers. They found that symptoms of deficiency resulted in three subjects on daily intakes of 0.38, 0.50, and 0.52 milligram respectively while two other subjects showed no symptoms on intakes of 0.61 and 0.65 milligram.

Melnick reported that women taking 0.7 milligram and men receiving 1.0 milligram per day gave no evidence of depletion. He found that normal individuals living on diets furnishing 1.0 milligram of thiamine daily when given additional thiamine promptly excreted larger amounts in the urine, while deficient subjects on the same additions did not. This was taken to indicate that 1.0 milligram was probably sufficient to saturate the tissues and the excess was excreted because it was not needed. Melnick concluded from these and similar studies that 0.35 milligram per 1,000 calories is probably the *minimum* requirement, but suggested allowing a factor of safety of about 50 per cent, making the requirement about 0.5 milligram per 1,000 calories.

Investigations undertaken by Williams, Oldham, Keys, Najjar and Holt, Hathaway and Strom, Foltz, and Glickman, working in different

laboratories, have made important contributions to our knowledge of the thiamine requirement. These studies have been reviewed by the Food and Nutrition Board of the National Research Council, and the conclusion drawn was that the minimal requirement for adults is approximately 0.23 milligram per 1,000 calories. In recognition of the wide differences found in the needs of individuals, 0.5 milligram per 1,000 calories has been recommended. Regardless of the calories, a minimum thiamine intake of not less than 1 milligram daily has been suggested. The recommended daily dietary allowance for the reference man needing 3,200 calories is 1.6 milligrams and for the reference woman needing 2,300 calories is 1.2 milligrams. For each additional 1,000 calories needed above the 3,000-calorie level an increase of 0.2 milligram of thiamine per 1,000 calories has been judged sufficient.

These generous allowances of thiamine take into consideration the fact that the animal body is capable of storing only a small amount of thiamine. It has been estimated that the adult human body does not contain more than about 30 milligrams of thiamine. Since the losses in the urine, feces, and perspiration must be replaced if health is to be maintained, the daily intake of thiamine must be adequate. See Tables I(a), (b), (d) and III(a), (c), (d) in the Appendix.

Studies of the requirement during pregnancy have not been as numerous. Those reported by Oldham and associates show that the same relationship exists between the requirement for thiamine and the calorie level as for other adults. Toverud in Norway as a result of studies made during World War II believes that the requirement is increased during pregnancy. The Food and Nutrition Board of the National Research Council has recommended 1.5 milligrams daily during the third trimester of pregnancy and during lactation. For recommendations for infants and children of different ages, see Tables I(a), (c) and III(a) in the Appendix.

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Ascorbic Acid

Discovery

It is again necessary to turn back the hands of time many centuries to the period when scurvy was a constant menace to sailors, soldiers, and explorers, and at intervals swept over great areas of land, especially in northern regions where people had to subsist for a large part of the year on a diet consisting mainly of grain products and meat or fish. The French crusaders are reported to have suffered greatly from it in the thirteenth century. On Jacques Cartier's second voyage to Newfoundland in 1535 "he wintered near an Indian village, Stavacona, in Quebec. Both the Indians and his crew were afflicted with scurvy. Between December and the middle of March, 25 men from his crew died, and the rest were so sick that recovery was despaired of except for three or four. The middle of March, Cartier noticed an Indian whole and sound who had been very ill with scurvy ten or twelve days earlier. He asked the Indian how he had healed himself and was told that he had taken the juice and sap of the leaves of a certain tree called 'Ameda'. At Cartier's request, the Indian had branches brought and showed how the bark and leaves should be boiled together and the resulting decoction taken every other day. So successful was the remedy that all Cartier's crew were speedily completely cured, and the narrator goes on to say: 'It wrought so well, that if all the physicians of Montpelier and Louaine had been there, with all the drugs of Alexandria, they would not have done as much in one yere as that tree did in sixe days, for it did so preuaile, that as many as used it, by the grace of god recouered their health.' He explains that the 'Ameda' is thought to be the sassafras tree, but this incident occurred in the middle of March at a season when 'our captaine' was walking

from his boat to the shore upon the ice at the time he saw the Indian who had been healed, so the 'Ameda' could not have been a deciduous tree. Lind believed it to be the American spruce." ¹

In 1747, this same Dr. Lind, who was a surgeon in the British navy, conducted a most interesting experiment to compare various articles of diet as to their antiscorbutic properties, using as subjects twelve sailors sick with scurvy on board the "Salisbury" at sea. They had one diet common to all, water gruel sweetened with sugar in the morning, fresh mutton broth oftentimes for dinner; at other times light puddings, boiled biscuit with sugar, etc., and for supper, barley and raisins, rice and currants, sago and wine, or the like. The men were divided into pairs. One pair had each a quart of cider daily; another, a spoonful of vinegar three times a day. Two of the worst had half a pint of sea water every day; two others had each two oranges and one lemon; two others had a most amazing compound of seeds, gums, etc., with a drink of barley water acidulated with tamarinds. The result of this nutrition experiment was that in six days "the most sudden and visible good effects were perceived from the use of the oranges and lemons." He recommended that thereafter lemon juice evaporated to a syrup should be carried in all ships for the safeguarding of the sailors, and in 1795 regular administration of lemon (called lime) juice was prescribed in the British navy, wherefore British sailors are today familiarly known as "limies." With the introduction of the potato into northern Europe scurvy greatly decreased on land, extensive outbreaks occurring only when crops failed or other misfortune deprived the people of their usual food.

Scurvy was considered a disease of adults, and the recognition of it as a dietary disease was far from universal a hundred years after the rule was made for its prevention in the British navy. In 1878 a famous English physician connected with the London Hospital for Sick Children, Dr. Cheadle, described three cases of scurvy in children under three years of age. Dr. Cheadle had made the Northwest Passage, sailing from Liverpool to Quebec in 1862, and hence had traveled across the American continent to the Pacific coast. On these wanderings he "learnt much about adult scurvy, small-pox, starvation, massacres and hairbreadth adventures." Returning to London, he found the doctors groping in darkness for the cause of the dreadful

¹ Appleton, V. B. "Spruce Beer as an Antiscorbutic." *Journal of Home Economics*, Vol. 13, page 604 (1921).

condition of the gums of certain children and recognized that it was scurvy. Then he asked, why did these children, out of all the number in the hospital, become scorbutic? An inquiry into the diet showed that one child for eight months had had only oatmeal, rusks, and water with a little mutton broth; another for three months had lived on bread and butter with a one-seventh share in a pint of milk together with a patent infant food; the third had been weaned at two years of age and then fed bread, butter, and tea with occasionally some sausage and a little brandy and water. Dr. Cheadle's answer to his own question was "potatoes," which most children of the poor were fed after they were weaned. His treatment consisted of unboiled milk with mashed potatoes beaten up in it, raw meat, and the juice of two oranges.

Five years later another great English physician connected with the same Hospital for Sick Children, Sir Thomas Barlow, published a classic paper "On Cases Described as 'Acute Rickets' which are Probably a Combination of Scurvy and Rickets, the Scurvy Being an Essential and the Rickets a Variable Element." Among the symptoms noted in one of the children were an excessively pale, sallow complexion, flabby muscles, continual moaning with a tendency to shriek when approached due to a "deep-seated pain connected with the bones." One of the peculiar symptoms was discovered to be hemorrhages into the muscles and under the periosteum of the bones of the legs. The diet, which had been wholly of dried milk and cereal with some beef extract, was changed to a pint and a half of cow's milk daily plus one-third cereal gruel or barley water, the juice of a quarter of a pound of raw beef, and two teaspoonfuls of orange juice. In three days there was a notable change, and improvement continued until in eight weeks this child could stand upright with a little support, "was of ruddy color and his skin and muscles had become quite firm." A diagnosis of scurvy in the absence of soreness and swelling of the gums was contrary to the classical sign of this disease and to be sure he was not dealing with rickets Sir Thomas referred some of his specimens of subperiosteal hemorrhage to Sir William Jenner who said positively that he had seen no such condition in rickets. So the conclusion was reached that while the disease had occurred in rickety children, the characteristic symptoms were not due to rickets at all, but were "truly scorbutic," and that marked improvement followed "a vigorous and especially an early antiscorbutic treatment."

Systematic Study of Antiscorbutic Foods

At the close of the nineteenth century it was known from practical experience that certain foods would cure scurvy and various theories had been proposed to account for the antiscorbutic power of these foods, none of which had proven tenable. Then in 1907 two Norwegian investigators, Holst and Frölich of the University of Oslo, stimulated by the success of Eijkman and others in producing experimental polyneuritis in pigeons by a faulty diet, undertook similar experiments in the hope of finding the causes of ship beriberi. Instead of pigeons they used guinea pigs and found to their surprise that when fed polished rice these developed, not beriberi, but *scurvy*. Further investigation showed that a diet of oats or any other grain or bread resulted in a scorbutic condition, but the feeding of grain plus a moderate amount of cabbage, dandelion, carrot, potato, or other fresh vegetable prevented the disease. Most significant was their finding that certain foods such as cabbage, carrots, and cauliflower lost their antiscorbutic property on heating or drying, while some others, such as potatoes and turnips and fruit juices, remained antiscorbutic after cooking. Fürst, working in the same laboratory, investigated dried peas, lentils, and almonds, and found that they resembled cereals in their lack of the antiscorbutic substance, but that when soaked and allowed to sprout they developed antiscorbutic properties. Uncertainty regarding the antiscorbutic substance arose partly from the fact that it was found impossible to induce scurvy in rats, but still more from the readiness with which seemingly slight changes in some foods caused loss of the antiscorbutic property, while similar changes in other foods had no such destructive effect.

The rat's immunity to scurvy was explained by the discovery that rat livers are antiscorbutic even when the animals have subsisted for a long time on a scorbutic diet. When the livers of such rats were fed to guinea pigs very ill with scurvy, the symptoms promptly disappeared and the animals gained rapidly in weight.

Hess and Unger in 1918 showed that the antiscorbutic substance could be extracted from orange juice with alcohol and would cure scurvy when given by injection directly into the blood stream. By 1920 the evidence was sufficiently clear and Drummond proposed that this antiscorbutic substance be called vitamin C.

Isolation and Identification of Ascorbic Acid

In 1921, at the Lister Institute in London, Zilva succeeded in making a preparation of this easily destroyed vitamin which would keep for several months if protected from air and light. Aside from the scientific contribution thus made to our knowledge of ascorbic acid, these researches brought at least one immediate practical return in connection with the British Air Route Expedition to Greenland in 1930–31. It so chanced that for over six months (October to May) one member of the party was isolated from the regular base and had to subsist, after the first month out, mainly on the sledging ration, consisting of pemmican, margarine, sugar, chocolate, cocoa, pea flour, and oats plus a casein preparation for additional protein with occasionally a teaspoonful of condensed milk. To guard against malnutrition, he added daily about 1 gram each of dried yeast and of a mineral salt mixture such as is used in laboratory studies, and one dessertspoonful of a lemon juice concentrate prepared by Zilva. Every second day he also included a dessertspoonful of cod liver oil. On a ration thus fortified, although forced to reduce the sledging ration by one-half as supplies began to run low, and although snowed up completely in his hut from the last of March to the beginning of May, he was able when relieved to ski about one mile unaided to the relief camp, and his teeth and gums remained in good condition so that he “could throughout bite hard uncooked food without discomfort.”

For eight years (1921–29) Zilva pursued his researches, getting still more concentrated solutions of vitamin C and learning more about its properties. Other investigators profited from his reports, and in this country in 1931 King of the University of Pittsburgh reported a concentrate of the active substance of lemon juice over 20,000 times as potent as the original juice. The next goal was the isolation of the vitamin in the form of pure crystals, and this ambition was realized within a few months. In April 1932, King and Waugh² reported the preparation of a crystalline compound from lemon juice which was active in preventing scurvy in guinea pigs. These crystals they found to be a hexuronic acid, a relatively simple chemical compound.

² Waugh, W. A., and King, C. G. “Isolation and Identification of Vitamin C.” *Journal of Biological Chemistry*, Vol. 97, page 325 (1932).

Often in research, independent lines of investigation suddenly converge and many perplexing problems in several fields are thereby illuminated. This has been strikingly so in the case of vitamin C. Research on the nature of biological oxidations, and especially of



(Courtesy of Professor C. G. King)

Fig. 77. Crystals of Ascorbic Acid

respiration in the leaves of plants, led to the discovery by Szent-Györgyi, at that time working in England at the University of Cambridge, of a substance in the cortex of the adrenal gland which he identified as hexuronic acid and suggested might have some relationship to a substance of similar properties which Zilva found in his concentrates of lemon juice but did not believe was vitamin C. It did not seem to Zilva that a vitamin could be as simple as hexuronic acid. But Szent-Györgyi was able to show that the hexuronic acid which he prepared from beef adrenal glands would protect guinea pigs from scurvy. He also discovered a very convenient source of

hexuronic acid in the Hungarian red pepper from which our commercial paprika is prepared. Other workers now were eager to extend these findings. They were supplied with sufficient material by Szent-Györgyi and Svirbely, then working at the University of Szeged in Hungary. Svirbely had gone from King's laboratory to do post-doctorate work with Szent-Györgyi. In King's laboratory he had learned King's method of purification of the vitamin and had assisted in the preparation of the then almost fabulous amount of a whole pound of vitamin C.

Crystals from lemon juice, adrenal glands, and red peppers were found to agree in antiscorbutic value, and distinguished organic chemists in Europe and America attacked vigorously the problem of chemical structure and synthesis. The first use made of chemically pure vitamin C was in treating a case of human scurvy, 40 milligrams being given a man by intravenous injection and effecting a prompt cure.

In 1933, Haworth of the University of Birmingham, England, and Karrer and Reichstein in Zurich established the structure and published the correct formula. Commercial synthesis followed, and ascorbic acid became the first pure vitamin available to the public by large-scale industrial synthesis. This comment from *Nutrition Reviews* is of interest: "The isolation and identification of ascorbic acid and its synthetic production on a large scale during the years 1932 to 1935 introduced a period of dramatic progress in the field of nutrition, a period in which much of our knowledge of the identity, chemistry and physiology of the vitamins was developed and the science of nutrition grew to take a foremost position among those sciences which contribute directly to the welfare and the health of man."³ In 1939, the name ascorbic acid was adopted by the Council on Pharmacy and Chemistry of the American Medical Association and became the official designation for this antiscorbutic vitamin.

Since the isolation of ascorbic acid in pure crystalline form, it has been shown that both the adrenal cortex and medulla of a normal guinea pig are very rich in ascorbic acid, but that the gland of a severely scorbutic animal contains practically none. The rat and the dog cannot be made scorbutic because they manufacture sufficient

³ Review. *Present Knowledge in Nutrition*, Chapter 14. The Nutrition Foundation, Inc. (1953).

ascorbic acid to maintain an adequate store of this vitamin in the adrenals.

It has been reported that in the United States the weekly production of synthetic ascorbic acid averages over 15 tons. This is equivalent to the amount of ascorbic acid in over 200 million oranges. According to a statement published by the American Medical Association, all pure ascorbic acid used in pharmaceutical products is prepared synthetically.

The Prevention and Cure of Experimental Scurvy

As has so often happened in human experience, knowledge of scurvy as a disease and the empirical discovery of a cure long preceded the identification of the antiscorbutic substance. For scientific study of any disease an experimental animal is necessary in order that conditions may be controlled and only one factor in a situation be varied at a time. A first step in the discovery of ascorbic acid was the observation by Smith of the Rockefeller Institute for Medical Research, in 1895, that guinea pigs kept upon a diet of oats and no fresh vegetables developed a hemorrhagic disease.

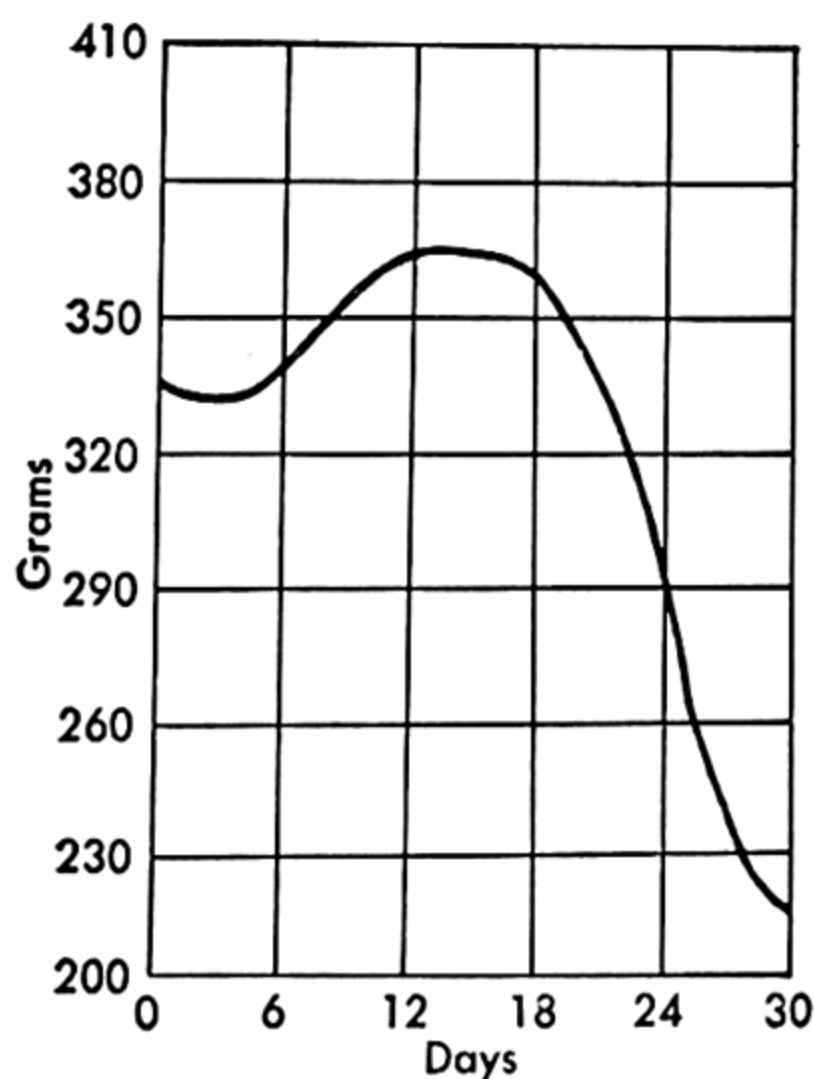
As has been pointed out earlier in this chapter, Holst and Frölich produced scurvy in guinea pigs in 1907 by feeding them restricted diets.

However, it was not until 1918 that a fully convincing demonstration was made by Cohen and Mendel that scurvy could be produced at will in guinea pigs by simply controlling the diet. They prepared a soybean cracker which contained all the then known essentials of an adequate diet and which the guinea pigs ate with great readiness. "At first their appearance was satisfactory. On about the tenth day, however, they exhibited a tenderness of the wrist and ankle joints, though they were still eating well and gaining in weight. Then the conditions became more severe. The joints swelled to twice or three times the normal diameter and spontaneous fracture of the wrist occurred in one animal. Appetite diminished and a sharp nutritive decline ensued."⁴

These are today recognized as characteristic symptoms of scurvy.

⁴ Cohen, B., and Mendel, L. B. "Experimental Scurvy of the Guinea Pig in Relation to the Diet." *Journal of Biological Chemistry*, Vol. 35, page 425 (1918).

If a healthy young guinea pig weighing about 300 grams is placed on a diet free of ascorbic acid, it continues to grow for about two weeks, then loses weight rapidly, and dies in from 26 to 34 days. A typical growth record is shown in Fig. 78. When the weight begins to fall steadily, the joints become tender and swell, the animal becomes relaxed and weak, as shown in Fig. 79, and frequently, because its gums and jaws are sore, will lie down with the side of its



(Courtesy of Professor H. C. Sherman and Miss S. L. Smith)

Fig. 78. Guinea pigs six to eight weeks old and weighing 300 to 350 grams placed on a scorbutic diet continue to grow for about 15 days, then lose weight rapidly and die of scurvy in from 26 to 34 days. The above curve is the average of 10 guinea pigs on a diet lacking ascorbic acid.

face on the floor of its cage in a typical "face-ache" position. The jaw bones suffer from absorption and appear eroded, the gums are spongy and bleeding, the teeth become loose and take irregular positions. The roots are absorbed and when the jaw is removed from the body and cleaned, the molars easily fall out, as shown in Fig. 80. The junctions of the ribs with the cartilages show "beads" similar to those in rickets and sometimes rib or leg bones are so brittle as to fracture spontaneously. At other times they fall apart at the joints, owing to the dissolution of the supporting cartilage, a condition easily mistaken for a fracture. The loss of calcium from the body is very great. Hemorrhages are common in the intestines, kidneys, adrenals, spleen, bladder, bone marrow, and periosteum, under the skin and in the muscles. They are due to interference with the nutrition of the capillaries which results in disorganization of their walls. There is also degeneration of cartilage cells all over the body and even muscle fibers have been found disintegrated.

When tissues or organs are low in ascorbic acid their respiratory activity is markedly decreased, showing that ascorbic acid is essential to the complex interplay of enzymes and oxidizable materials in-

face on the floor of its cage in a typical "face-ache" position. The jaw bones suffer from absorption and appear eroded, the gums are spongy and bleeding, the teeth become loose and take irregular positions. The roots are absorbed and when the jaw is removed from the body and cleaned, the molars easily fall out, as shown in Fig. 80. The junctions of the ribs with the cartilages show "beads" similar to those in rickets and sometimes rib or leg bones are so brittle as to fracture spontaneously. At other times they fall apart at the joints, owing to the dissolution of the supporting cartilage, a condition easily mistaken for a fracture. The loss of calcium from the body is very great. Hemorrhages are common in the intestines, kidneys, adrenals, spleen, bladder, bone marrow, and periosteum, under the

volved in the combustion of the fuel foods. Even more easily observable than the relationship to tissue respiration is the influence which ascorbic acid exerts on the structure of tissues. The widespread degenerative changes all over the body in scurvy have been found



Fig. 79. The Lowest Animal is Normal. The Two Upper Ones Show Characteristic Positions of the Scorbutic Guinea Pig

by Wolbach, Howe, Bessey, and others working in this field to be due to the inability of supporting tissues to produce and maintain intercellular substances. This inability of tissues to produce inter-



Fig. 80. The Jaws of Two Guinea Pigs

The one on the left is from an animal fed plenty of ascorbic acid; the one on the right, from a scorbutic animal. The deterioration of the jaw bone has permitted the molar teeth to fall out.

cellular material according to Wolbach is the underlying cause of the following:

- (1) Hemorrhages which may occur anywhere in the body.
- (2) Profound changes in the structure of the teeth and gums.
- (3) Changes in the growing ends of bones with beading and other deformities which in earlier times were mistaken for rickets.
- (4) The falling apart of bones due to loss of supporting cartilage.
- (5) Enlargement of the heart.
- (6) Degeneration of muscle fibers generally, causing extreme weakness and even death.
- (7) Anemia due to failure of the tissues that form red blood cells and loss of blood by hemorrhage.
- (8) Loss of calcium through degeneration of the bone matrix so that it is no longer able to retain the mineral salts and the bones become so soft that they break spontaneously.
- (9) The degeneration of the sex organs.

In fact, the lack of ascorbic acid is the cause of such widespread disorganization that it is amazing that scurvy can be latent for so long a time before the onset of pain and occurrence of marked out-

ward symptoms. It is also surprising how rapidly improvement follows the administration of the vitamin if it is given before the condition has advanced too far. In 24 hours formation of new "cement" material has been demonstrated in both bones and soft tissues. Young animals which have become helpless from paralysis in the hind legs soon recover.

Ascorbic Acid and Wound Healing

As long ago as 1769 it was recorded in the report of Anson's voyage that "the scars of wounds which had been for many years healed were forced open by this virulent distemper" (scurvy). Pirani and Levenson⁵ of the United States Army Medical Nutrition Laboratory in Chicago, in 1953, demonstrated a similar condition occurring in guinea pigs. The animals were reared on an adequate diet and when they weighed 450 grams an incision 4 centimeters in length was made in each animal and allowed to heal for 6 weeks. At this time half of the animals were placed on a diet free of ascorbic acid and the other half remained on the control diet. Those on the scorbutic diet developed signs of scurvy within 17 to 18 days and severe symptoms by the twenty-sixth day when swelling, herniation, and hemorrhages were noted in the scars of the deficient pigs. No such changes occurred in the controls. This study demonstrates clearly not only the need for ascorbic acid for normal healing of a wound but for the maintenance of previously formed scar tissue.

In 1937 Lanman and Ingalls directed attention to the importance of liberal intake of ascorbic acid for surgical patients. Following this Crandon, Lund, and Dill in 1940⁶ reported a study of the development of scurvy in a normal human being. Crandon himself was the subject of the experiment, living on a scurvy-producing diet for 6 months and 18 days. The first signs of scurvy, hemorrhagic areas around the hair follicles of the legs, did not develop until after he had lived on this diet for 5 months. During the fourth and fifth months he experienced slight lassitude and ease of fatigue but marked fatigability did not develop until the sixth month. When he

⁵ Pirani, C. L., and Levenson, S. M. "Effect of Vitamin C Deficiency on Healed Wounds." *Proceedings of Society of Experimental Biology and Medicine*, Vol. 82, page 95 (1953).

⁶ Crandon, J. H., Lund, C. C., and Dill, D. B. "Human Experimental Scurvy." *New England Journal of Medicine*, Vol. 223, page 353 (1940).

had been on the diet for 3 months a 2½-inch cut was made in the lower part of his back. After 11 days it was found that the wound had healed quite normally, but when another cut was made on the other side of his back, after 6 months on the diet, and examined after 10 days, no healing had taken place. The subject was then given daily 1 gram of ascorbic acid intravenously for 10 days in succession while continuing on the scurvy-producing diet. Satisfactory healing of the wound resulted, and a new incision made directly across the healed area also healed normally.

Other effects of this scorbutic diet were seen in the blood. The ascorbic acid level of the plasma fell to zero in 42 days and that of the white cells in 122 days, but anemia did not result. It is believed as a result of this experiment and observations of others on surgical cases that deficiency of ascorbic acid may well be a cause of the failure of some human wounds to heal and that the diets of surgical patients should therefore be planned to furnish high amounts of ascorbic acid.

Changes in the Teeth

In the days when the Roman soldiers were campaigning on the Rhine, they suffered, after the campaign had lasted two years, from loosening of the teeth, and a remedy was discovered in the eating of a native plant thought by modern writers to be some variety of sorrel. Swelling and bleeding of the gums and progressive loosening of the teeth have always been accounted characteristic symptoms of human scurvy, and in their early researches Holst and Frölich noted the same symptoms in guinea pigs. But actual changes in the structure of the tooth itself were first reported in 1916 by Jackson and Moore, who noted hemorrhages in the pulp of the teeth in guinea pigs. Soon after, in 1919, Zilva and Wells showed that scurvy produced great changes in the teeth of both guinea pigs and monkeys and discovered that the tooth is one of the first parts of the body to be affected by any shortage of ascorbic acid. They found that when the mildest degree of scurvy could barely be detected upon post-mortem examination, profound changes in tooth structure had already taken place.

In this country Howe was also actively engaged at this time in studying the effects of diet on teeth, and described changes not only in the gums and pulp, but also in the enamel and dentine which

could be cured by addition of orange juice to the diet. Zilva and Wells had noted that the odontoblasts of the teeth of scorbutic guinea pigs became disorganized, and their work was soon extended by Höjer of Sweden, who in 1924 found that when not enough ascorbic acid was given to promote growth, but only that small amount which would arrest decline in weight for several weeks, changes could still be detected in the teeth by the second week, while on a completely scorbutic diet they appeared within a week. The first change occurs in the odontoblasts, which make the nutritional connection between the pulp of the tooth and the dentine. When ascorbic acid is not entirely lacking in the diet but is present in too small quantity, the odontoblasts, which ordinarily stand in a row side by side like the pickets of a fence, lose their orderly arrangement and change their character. They shrink away from the dentine, which in turn begins to degenerate, becoming liquefied and later being replaced by "secondary dentine" which is more like bone than like the original dentine. There is also injury to the pulp, sometimes resulting in large hollows filled with fluid. In the guinea pig about twice as much ascorbic acid is needed for complete tooth protection as for the prevention of the ordinary signs of scurvy.

A study by Fish of the Royal Dental Hospital, London, and Harris of Cambridge University showed that the enamel-forming cells (ameloblasts) are not affected as soon as the odontoblasts nor by as mild a degree of scurvy, but when the disease is severe "they either disappear altogether or become hard and shriveled so that even if the animal is cured there never will be any enamel on that section of the tooth which was forming when the disease was at its height."

The cementum, which covers the part of the tooth imbedded in the jaw, is secreted by cells (cementoblasts) which undergo degeneration, so that no cementum is produced, and its place is taken by a scar tissue with calcium deposits similar to that laid down to protect the pulp (secondary dentine). In short, deficiency of ascorbic acid appears to affect all cells concerned with the laying down of the hard tissues—dentine, enamel, cementum, and the bone of the jaw. Crampton in 1947 suggested a bioassay method for ascorbic acid based on the growth of the odontoblast cells of the incisor teeth of young guinea pigs.

Just how all these findings apply to human teeth is not yet entirely clear, but they have served to emphasize the far-reaching role of

nutrition in tooth health. No animal except the monkey has been found sufficiently like the human being in tooth structure and food requirements to serve as a satisfactory testing agent. Westin, in collaboration with Höjer, studied 18 cases of human scurvy and reported degeneration of the odontoblasts, and changes in pulp, dentine, and cementum similar in many respects to those observed in guinea pigs' teeth. The extensive studies of Lady Mellanby on the relation of the structure of the teeth to dental disease and especially as a factor in dental caries, while largely conducted on dogs which do not get scurvy and hence give no direct evidence in regard to the role of ascorbic acid, indicate very strongly a definite relationship between poor tooth structure and susceptibility to caries, and the relationship of ascorbic acid to every kind of tooth-building cell justifies emphasis on ascorbic acid as a factor in tooth health and development.

Changes in the Bones

In his treatise on *Scurvy Past and Present*, Hess pointed out as long ago as 1920 that many infants presenting no symptoms of acute scurvy might still be anemic and fretful, weak and retarded in growth because of a subacute or latent form of the disease which no one had learned to recognize. In 1923, a comprehensive study of rickets undertaken in New Haven, Connecticut, under the auspices of the Children's Bureau of the United States Department of Labor, by Eliot revealed a number of instances in which unsuspected scurvy was discovered by means of X-ray examinations. Since then, bone changes in scurvy have been studied in great detail, particularly by Park⁷ of the Johns Hopkins University. Rickets is a disease of the entire bone; scurvy affects the growing ends. In rickets, the bone tends to bend; in scurvy, to break. The ribs show beading at their junction with the breast bone exteriorly resembling rickets (Fig. 81). The disturbance of growth renders the junction weak and nature tries to compensate by broadening the opposing surfaces of the junction. The cartilage cells continue to grow at the end of the shafts until severe scurvy develops, but the activity of the bone-forming cells is arrested and there is no increase in thickness of the bone. Furthermore, the bone already formed begins to grow thin as the cells can

⁷ Park, E. A., Guild, H. M., Jackson, D., and Bond, M. "The Recognition of Scurvy with Especial Reference to the Early X-ray Changes." *Archives of Diseases in Childhood*, Vol. 10, page 265 (1935).

no longer hold the mineral salts. The regions in which these changes are greatest are the ones which in health are the site of most active development. The middle ribs become especially fragile at their anterior ends because of their exceedingly rapid growth and, under strain, give way. Also factors of strain which in health stimulate growth of new bone hasten the destructive process in scurvy.

One of the most characteristic changes is the occurrence of hemorrhages at various points in the bone itself, in the marrow or under the periosteum. Subperiosteal hemorrhages develop only when the involvement of the bone has reached an advanced stage. They originate at the ends of the bone and extend toward the middle. When the bone begins to give way, and fractures occur, the periosteal blood vessels are torn and the blood escapes under sufficient pressure to loosen the periosteum, which is more easily detached in scurvy than in health.

It is of interest that in the studies of the boys in Christ's Hospital in the years 1918-22, one of the results of the deprivations of the war years was the increased number of fractures, which decreased again as soon as the diet was improved. While attributed to low vitamin D and calcium, there was also an increase in the incidence of rheumatism during the same years, which fell off as sharply as the fractures when the diet was improved. Such vague pains often arise from lack of ascorbic acid. The increase in milk (which was probably unpasteurized) and in fruits and vegetables in the diet, would have materially increased the ascorbic acid content of the diet and perhaps best explain the decline in fractures and rheumatism.

Changes in the Blood Vessels

The hemorrhages which are so characteristic of scurvy are due to the failure of the intercellular cement substance in the walls of the



(Courtesy of Dr. Rustin McIntosh)
From Jolliffe, Tisdale and Cannon, *Clinical Nutrition*. Paul. B. Hoeber, Inc. (1950).

Fig. 81. A Case of Scorbutic Rosary in an Infant

blood vessels, so that the capillaries become very fragile and rupture under strains which would ordinarily have no such effect. Since the changes in the capillaries are one of the earliest to occur in ascorbic acid deficiency, it was thought that a capillary test might be developed based on the application of different degrees of pressure on the skin. Göthlin in Sweden developed a capillary test which he used on children, and Dalldorf in the United States developed another method of applying a capillary resistance test which was also used to determine subacute scurvy in children. It is now recognized that these tests are not specific for scurvy, but they have demonstrated the effectiveness of ascorbic acid in helping to strengthen the blood vessel walls. Göthlin describes the recovery of a twelve-year-old country girl who had typical scorbutic gums. They were swollen, spongy, and red, and some of her teeth were slightly loose. "I shall never forget how this little girl with the dull, tired, resigned expression of face, through five weeks of intensive treatment with orange juice awakened, so to speak, how her movements became livelier and her eyes grew bright, and how her looks showed what pleasure she got out of life."⁸

Grusin and Kincaid-Smith,⁹ in 1954, reported finding 30 cases of scurvy in adults among the South African Bantu. In every patient hemorrhage was found in the muscles of the lower limbs which was accompanied by pain in the legs. Twenty-four showed a bleeding tendency and/or hypertrophic gums. Both legs were affected in 20 of the patients and invariably the hemorrhage was found in the calf of the leg; in 10, the hemorrhage was more generalized, affecting the entire calf. Paradoxically, the disease appeared more frequently in the spring and summer when fruit and green vegetables were more plentiful and inexpensive, probably due to the poor food habits of these individuals. More men than women developed scurvy and it was rarely found in children.

Thomson in Scotland in 1954 reported finding 100 cases of florid scurvy in the general hospital in Glasgow during a period of 15 years. Only 6 of these cases were women. Fifty-two of these patients

⁸ Göthlin, G. F. "A Method of Establishing the Vitamin C Standard and Requirements of Physically Healthy Individuals by Testing the Strength of Their Cutaneous Capillaries." *Skandinavisches Archiv für Physiologie*, Vol. 61, page 225 (1931).

⁹ Grusin, H., and Kincaid-Smith, P. S. "Scurvy in Adult Africans." *The American Journal of Clinical Nutrition*, Vol. 2, page 323 (1954).

reported that they lived alone or in lodging houses where they did their own cooking. Eighty were found to have sheet hemorrhages in the lower limbs or widespread subcutaneous extravasation of blood either spontaneous or following minor trauma. Eighty-two showed moderate or severe anemia. Complete recovery following treatment occurred in 95 patients. Thomson suggests that there are almost certainly several minor cases never seen by the doctor for each case which comes under medical care and that subclinical scurvy may cause a good deal of the vague general ill-health wrongly attributed to "old age."

Resistance to Infection

Ascorbic acid is concerned with factors which hold cells together in specialized tissues and organs, and its withdrawal means widespread disintegration. As has already been shown, the walls of the blood vessels, the marrow and the calcified portions of the bones, the connective tissue wherever found, even the nerves, are involved in the general collapse. Teeth are loosened from their sockets, their roots absorbed; the walls of the lungs cave in, owing to dissolution of connective tissue; the capillary walls give way and blood stagnates in minute pools, making slight hemorrhagic spots called petechiae. The bones lose their calcium because the connective tissue is unable to hold it, and symptoms similar to rickets are observed.

It would be strange if under such circumstances bacteria of many sorts did not find ready access to organs and tissues and aid in their deterioration. Hess called attention to the fact that in infants one of the striking and important symptoms of scurvy is susceptibility to infection. In the earlier investigations of the effects of scurvy on guinea pigs, animals which had been fed adequate amounts of antiscorbutic food were found to be less susceptible to inoculations with certain organisms of low virulence obtained from the tissues of other guinea pigs affected with scurvy, than poorly fed animals. More recently latent scurvy has been induced in guinea pigs and the animals' resistance to infection tested by dosage with various microorganisms. Inoculation with 1,000 million pneumococci was fatal to all those with the limited ascorbic acid intake, while those with a liberal supply were quite resistant. Experiments with other common types of bacteria have given similar results, showing how important a liberal supply of this vitamin is for full protection.

Several tests of the power of guinea pigs to resist the tubercle bacillus have shown that in the scorbutic animal tuberculosis develops more rapidly than in the nonscorbutic. These studies aroused interest in the relation of ascorbic acid to human tuberculosis and it is now well established that in this disease the requirement is greatly increased.

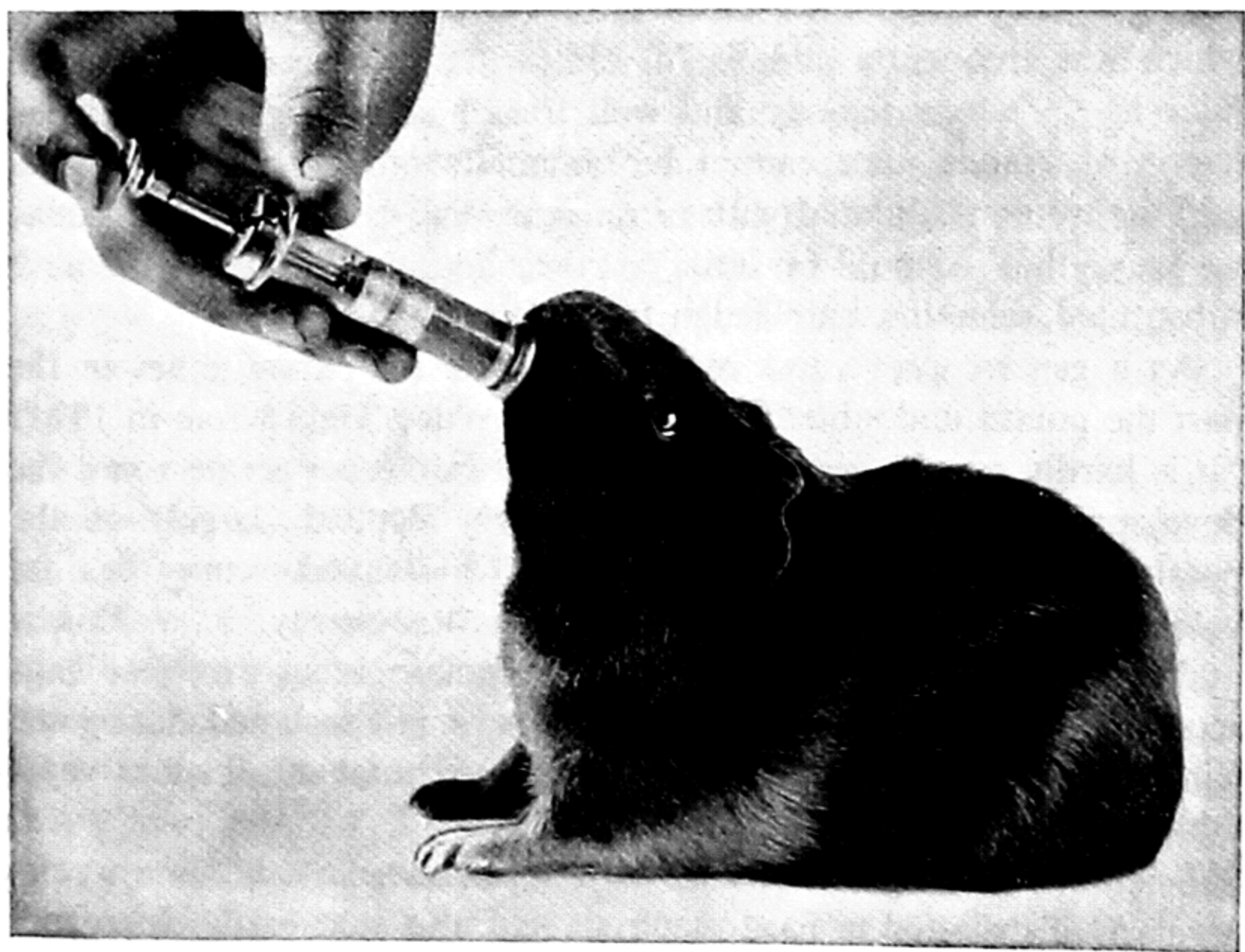
Increased resistance to a bacterial toxin due to ascorbic acid has been demonstrated by King and Menten who gave guinea pigs two different dosages and then injected diphtheria toxin four times within 29 days. Before there were any signs of scurvy, animals on the lower ascorbic acid intake averaged three times as much loss in weight. It was further found that in addition to greater injury to the tissues, the toxin caused a definite loss of ascorbic acid from the adrenals, pancreas, kidneys, and liver. This is in harmony with an experience of Dry in Africa, who as Medical Officer of the Rhodesian Railway had to deal with an outbreak of scurvy among the native laborers. They had been fed a diet according to government regulations, which included all the essentials of an adequate diet, but the natives were beset with intestinal parasites and could not utilize the vitamin when taken by mouth. The only successful mode of treatment was to inject orange or lemon juice directly into the blood stream.

Measurement

As in the case of thiamine, the first methods of measuring the ascorbic acid content of foods were biological. The guinea pig was the animal used because no other common laboratory animal develops scurvy. Two biological methods were developed; namely, Höjer's, in which disturbance of the tooth was taken as the first sign of scurvy, and the feeding method, perfected by Sherman, LaMer, and Campbell, in which feeding was conducted through a 90-day period (if the animals lived that long) and then post-mortem examinations were made for such signs of scurvy as hemorrhages into ribs, joints, muscles, and intestines and fragility of the bones, as tested in the jaws, teeth, ribs, and joints. A unit was defined as the smallest dosage which would protect the animal against all signs of scurvy for 90 days. The amount required for the protection of the tooth was found to be approximately twice that required for protection against any other signs of scurvy.

With the synthesis of ascorbic acid, the possibilities for quantita-

tive research were greatly increased, and the development and use of chemical methods became the objective, the most commonly used reagent being 2,6-dichlorophenol indophenol as a titrating agent or in spectrophotometric methods. This pink indophenol dye in acid solution is rapidly decolorized by ascorbic acid. The dye solution is first standardized against a solution of known concentration of the pure vitamin and then can be used to titrate unknown solutions and determine their ascorbic acid potency. This test has been especially useful because it affords a means of measuring the concentration of ascorbic acid in blood and urine, thus making it possible to determine the requirement of ascorbic acid.



(Courtesy of Dr. H. Goss)

Fig. 82. A Guinea Pig Being Fed a Measured Amount of Orange Juice to Test Its Ascorbic Acid Value

The International Unit for ascorbic acid is defined as 0.05 milligram of the pure, crystalline substance, but is rarely used now, it being considered more satisfactory to express these values in milligrams.

Sources

Ascorbic acid is produced by the plant in the process of its growth. It is not present in dry mature seeds, but develops as soon as they begin to sprout. It is abundant in actively functioning and succulent fresh green leaves where, as Szent-Györgyi has shown, it is essential for the respiration of the plant. Old-time remedies for scurvy, such as fir tops, pine needles, water and garden cresses, juices of scurvy grass, nettles, burdock, dandelions, field daisies, and turnips, as well as oranges and lemons, attest the wide range of vegetable sources discovered by man in the past. It must be noted, however, that many decoctions were boiled so long that it is probable that they owed their chief value to the orange or lemon juice which was frequently added. An old writer, who commends lemon juice as "precious remedy and well tried," also suggests that when lemon or orange juice cannot be obtained "nitre dissolved in vinegar" or water acidulated with nitric acid may be substituted. Today we know that it would be futile to place hope in the latter. We have substituted scientific knowledge for tradition.

As a general preventive of scurvy in the temperate zones in the past the potato undoubtedly has held first place. Hess wrote in 1921: "It is hardly an exaggeration to state that in the temperate zones the development or nondevelopment of scurvy depends largely on the potato crop. In Ireland, when the potato has failed, scurvy has developed. The same thing has been true in Norway. . . . This is attributable in part to the fact that the potato is an excellent antiscorbutic, but to a greater extent because it is consumed during the winter in amounts that exceed the combined total of all other vegetables."

Scientific investigation has shown that ascorbic acid is very irregularly distributed in food materials and also very easily destroyed. It is necessary to know the conditions under which a food has been secured, the processes to which it has been subjected in preparation for the table, as well as its original store of the vitamin, to determine its practical value as an antiscorbutic. Fresh raw cabbage contains more ascorbic acid than fresh raw potato, but there is little loss in cooking the potato whereas the cabbage rapidly loses its antiscorbutic value when it is cooked too long. The parsnip, so popular in parts of Canada, is another root vegetable which compares favorably with the potato as a source of ascorbic acid.

Apples vary greatly with variety. Storage results in considerable loss, most of the vitamin having disappeared after nine months in an ordinary cellar, and about one-fourth after six months in cold storage. Cooking destroys much of what is present in the raw flesh, so that apple sauce is not an antiscorbutic, as a man found to his sorrow who undertook to live on milk, whole grain cereals, and apple sauce when in financial straits, and after a time became a patient in a hospital and was diagnosed as a case of scurvy. Raw apples, eaten skin and all, in generous quantities, have undoubtedly provided protection in many a country home in the days before the cause of scurvy was so well understood, and before oranges and tomatoes were so readily available as protective foods. An interesting result of the search for new sources of ascorbic acid in England was the discovery that rose hips are rich in this vitamin and practical to use.

Animal foods are less satisfactory sources of ascorbic acid. Eggs have none. The concentration in liver is usually somewhat higher than in muscle. The amount in fresh raw milk depends upon the diet of the cow, but in practice varies less with the season than generally supposed. The care of fresh milk is also a factor, since a bottle of milk standing in the sun for half an hour loses most of its ascorbic acid.

When milk is pasteurized to destroy microorganisms the amount of ascorbic acid lost will depend upon the conditions under which the heating is conducted. Milk brought rapidly to the boiling point, held there two minutes, and quickly cooled, loses less than that pasteurized for twenty minutes at 165° F. Since ascorbic acid is so important for the welfare of the infant, it has become a routine practice to give all infants some food of high antiscorbutic value, such as orange juice, instead of trying to depend upon milk for this vitamin. Human milk has been found to be two to three times as rich as cow's milk.

Heating, drying, and aging have all been shown to be factors in the destruction of ascorbic acid, but operating differently with different foods, and demanding consideration of time, temperature, and other factors contributing to oxidation. Unless one has specific knowledge of the ascorbic acid content of foods generally it is best to establish a habit of eating regularly some food or foods of high antiscorbutic value. The regular consumption of not less than one-half cup of orange juice in the daily diet is a protective measure of great value, even when potatoes and other fruits and vegetables are

included, and nothing short of imperative when food shortage or economic stress forces dependence on milk and cereals for most of the ration.

For the full conservation of our food resources, it is necessary that certain amounts be frozen, canned, concentrated, or dried. Some kinds, as milk, orange juice, and lemon juice, have been commercially dried with little if any loss of antiscorbutic value. Vegetables are likely to lose less in commercial canning than in ordinary home cooking. Fresh market vegetables may lose as much as half their ascorbic acid by the time they reach the city consumer, 24 to 48 hours after gathering. One of the advantages of a home garden lies in the possibility of using the vegetables as soon as they are gathered. Vegetables preserved by commercial quick freezing lose practically no ascorbic acid while in the frozen state, but are subject to the same losses between picking and freezing and will also lose their ascorbic acid quickly when they are thawed, so they should be cooked before they are entirely thawed out. For the conservation of ascorbic acid the cooking of vegetables should be done as quickly as possible, and the juices retained whenever feasible.

The many varieties of citrus fruits have long been recognized as the most dependable sources of ascorbic acid throughout the year in the markets of the United States. It is of interest, though, to note that in many of our markets certain tropical fruits which are good sources of ascorbic acid are appearing more commonly, such as the mango and papaya. The guava is another tropical fruit with a high ascorbic acid content but is not yet as commonly used here.

The richest source of all is the acerola, known as the West Indian cherry, which has an average potency of ascorbic acid 30^{10} times that of orange juice. Asenjo and his associates at the School of Tropical Medicine in Puerto Rico first reported the high potency of the acerola in 1946, and this has since been confirmed in a number of laboratories. The acerola tree has apparently grown wild in Puerto Rico for over 2,000 years and it took 8 years of experimentation to develop this variety of cherry as a cash crop. The cherry is now sufficiently available for its juice to be added to a few of the less potent canned fruit juices. One cherry will provide the recommended daily allowance for ascorbic acid. It has been suggested that every school in Puerto Rico should have acerola trees in its yard.

¹⁰ Values as high as 80 times that of orange juice have been reported.

Other good sources of ascorbic acid are the green leafy vegetables (if not cooked too long), fresh peppers, various melons, and berries (particularly strawberries) in season. Figure 83 shows a



Fig. 83. Food Portions Yielding about 23 Milligrams (Ten Shares) of Ascorbic Acid

	<i>Grams</i>		<i>Grams</i>
Bananas, A.P.	349	Orange juice	44
Peaches, A.P.	382	Tomato juice	147
Watercress	39	Pepper, green	19
Cantaloupe, A.P.	149	Grapefruit	58
Cabbage	47	Tomato, A.P.	112

selection of common foods having the same content of ascorbic acid. For a more complete listing of the ascorbic acid values of foods see Tables II and IV in the Appendix.

Requirement

In making recommendations for the daily dietary allowances for ascorbic acid the Food and Nutrition Board of the National Research Council based their decision on the following: "(a) intakes known to protect against severe or mild signs and symptoms of scurvy, for individuals ranging in age from infancy to maturity; (b) the quantity supplied to infants by human milk when the mother's intake of

vitamin C is characteristic of good diets; (c) human and animal intakes that maintain specific functions such as wound healing, enzyme activity, cellular proliferation, and resistance to common stresses; (d) variations in tissue concentration that result from different intakes, and related observations of the risks of tissue injury or functional disturbance; and (e) comparative studies in nutrition, including animals that require vitamin C for protection from scurvy (guinea pigs and primates) and animals that maintain a 'normal' concentration of the vitamin by tissue synthesis."¹¹ The recommended daily dietary allowance for the "reference man" has been set at 75 milligrams of ascorbic acid and that for the "reference woman" at 70 milligrams with allowances of 100 and 150 milligrams for pregnancy (third trimester) and lactation, respectively. For recommendations for other individuals, infants and children, see Tables I(a), (b), (c), (d), and III(a), (b), (c), (d) in the Appendix.

These are not actually saturation levels since even higher intakes have been reported to provide for higher concentrations in the tissues. In general the lower the intake of ascorbic acid, the smaller is the amount found in the blood and urine and when the intake is raised gradually, a level is found at which there is a large increase in the amount found in the urine and at the same time the amount in the blood reaches a level not increased by further additions, these being largely excreted. The body is then thought to be in a state of saturation as to ascorbic acid. There is not complete agreement as to whether it is necessary to keep the body saturated, but there seems to be no doubt that amounts considerably in excess of those only sufficient to prevent scurvy or other signs of ascorbic acid deficiency are needed for the maintenance of good health. Now that we know that infections, excessive loss of fluid from the body in perspiration, and other conditions commonly met with in daily life increase the need for ascorbic acid, it would seem wise to keep the body generously supplied with this vitamin at all times.

Ascorbic acid has a marked effect on certain enzymes and is involved in many metabolic processes. It plays a role in the metabolism of protein and the amino acids, tyrosine and phenylalanine. Its role in carbohydrate metabolism has not yet been clearly elucidated. It is involved in the metabolism of certain mineral elements (calcium,

¹¹ Food and Nutrition Board. *Recommended Dietary Allowances*, page 19. National Research Council (1953).

phosphorus, iron, copper, and probably others) as well as that of a number of the vitamins (vitamins A, D, thiamine, riboflavin, pantothenic acid, folic acid, and vitamin B₁₂). Along with its importance in maintaining adrenal integrity, it is essential for a normal rate of cholesterol synthesis. It has been reported beneficial in many clinical conditions such as rheumatic fever, muscular fatigue, pernicious anemia, arthritis, and others. Studies of the ascorbic acid status of human beings here in the United States have shown that many people are living on diets too low in this vitamin.

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Vitamin D

Rickets

The discovery of vitamin D, like that of vitamin A, thiamine, and ascorbic acid, came about partly through practical experience with a baffling nutritional disease and partly through researches on the effect of experimental rations upon laboratory animals. Learning how to control xerophthalmia, beriberi, and scurvy excited fresh interest in another disease in some way connected with diet but having a peculiar geographic distribution—rickets, at one time the commonest nutritional disease of children in the temperate zone.

It is thought that rickets first appeared as a menacing disease in the great towns in the low countries of northern Europe, although it probably existed in England before the days of the Romans. Its prevalence in severe form in the British Isles led to its being called early in the seventeenth century the "English Disease." The first treatise on the subject by an English author was written in Latin and published as a thesis for the degree of Doctor of Medicine at Leyden in 1645 by Daniel Whistler. The great classic on the subject appeared in 1650, also written in Latin by an English physician of great distinction who was for over thirty years "Professor of Physic" at Cambridge, Sir Francis Glisson.

For two centuries after Glisson its cause remained a mystery, and as it is a disease which does not cause death but only makes life miserable, it did not excite much interest in times when many other miseries abounded. It was recognized as a disease of the bones, in which, as one writer quaintly said, "The head waxeth too great, whilst the legs and lower parts wain too little." The state of knowledge

even in the latter part of the nineteenth century was empirical rather than scientific as will be indicated in the following excerpt from an old household guide, "information for everybody," bearing the date of 1874.

"As the cause of this disease is an absence of the mineral salts, the natural remedy for the case would seem to be to give the system those salts of which it stands in need, namely, the phosphates of lime and soda. The cure, however, cannot always be effected by these means alone, though given in constantly repeated doses; the restoration to health can only be attained by a steady and gradual system of dietetics and regimen. The first indispensable requisite is change of air, and if possible, to the seaside; . . . an abundance of milk, and a full, rich diet—animal and vegetable—with fruit; the patient in this instance being enjoined to eat the rind or skin as well as the fruit, and when the digestion is good, water-cresses, radishes, salad, and any crude vegetable in which the mineral salts are in their natural abundance. . . . Though the diet and regimen are the chief agents required in the treatment of rickets, some medicine is necessary, and of that we shall now proceed to speak. In the first place, cod liver oil, on account of the nitrogen or animalizing principle it contains, has been greatly recommended in this disease, and there can be no doubt that in cases of much debility it may be given with very great effect."

Apparently little heed was paid to cod liver oil as a specific for rickets for another quarter of a century. In 1909, Schabad of the Children's Hospital in Petrograd took a four-year-old child who had been rachitic since it was a year and a half old, unable to stand or walk, and administered cod liver oil with the result that in a few days calcium and phosphorus retention increased remarkably and in two months the child was normal. Up to this time it had been customary to give phosphorus with the cod liver oil, and any good effects had been attributed to the phosphorus, but this and other experiments of Schabad made it clear that the oil itself was responsible.

In 1917 new interest was aroused in cod liver oil therapy in this country by Hess and Unger who noted the very high incidence of rickets among Negro babies in the Columbus Hill district of New York City and sought to test the efficacy of cod liver oil as a preventive measure. Over 90 per cent of the colored babies had the disease,

the infant mortality rate was the highest in the city, and respiratory diseases, to which rickets is a predisposing cause, played a large role in the death reports. From December to June, cod liver oil was given to about 50 babies between the ages of four months and one year, frequent visits being made to the families for periodic physical examinations and to see that the oil was being taken. Infants under six months were given one-half teaspoonful of oil three times a day and older infants twice this amount. Of 32 children who received the oil for six months all but 2 were fully protected; of 12 who received it for only four months, 5 were found to show symptoms of rickets; and 16 who received none were all rachitic. It is interesting to note that the report of this work "gradually spread throughout the district, and the ordinary symptoms of rickets became the common knowledge of the mothers, who often brought their babies to the consultation with the request that cod liver oil be administered"; and shortly afterward the New York City Department of Health established a rickets clinic in connection with its baby welfare station, where cod liver oil could be dispensed at cost.

Further interest in rickets was stimulated by the acute outbreak of nutritional disorders of bones not only in children but also in adults in Germany, Austria, and Poland at the close of the first World War. In Vienna the disease was particularly bad, and this city became the seat of the investigations of Dalyell and Chick sent by the Lister Institute of London to study the situation. They began investigations in the autumn of 1919, at one of the principal medical centers of the Health Insurance Organization of Vienna. Between January and May (1920) over six hundred applied for help, of whom about one-third were chosen for special study. Most of the cases were middle-aged or elderly people who had been living on a diet restricted to bread and vegetables mainly, with small amounts of flour and sugar—no milk, meat, eggs, butter, or other fat. Their disease corresponded closely in character with rickets, which was also so widely prevalent that every child in central Europe was said to have been rickety at that time. In rickets there is a failure to deposit calcium and phosphorus in the growing bone. In the corresponding disease of adults, called osteomalacia, the bones soften as the calcium and phosphorus already deposited there are withdrawn and excreted. The first symptom of the disease is difficulty in walking and a peculiar shuffling, waddling gait; as it progresses movements become more

difficult and the hands and arms are used as much as possible to save the lower part of the body. To effect a cure various additions to the diet were tried. Increasing the total calories with cereals and sugar had no effect on the bone disease, nor were about a pound and a half of green vegetables of advantage in this respect though they caused some increase in weight. But cod liver oil effected a speedy cure, when 30 to 40 grams ($2\frac{1}{2}$ to 3 tablespoons) were given daily. There was great improvement within a week, in 12 days a very much crippled patient moved with ease and in 18 days could "spring from bed without use of the hands."

Experimental Rickets

Among the confusing observations in regard to the etiology of rickets one of the most puzzling was that the apparently well-fed child often fell a victim to the disease and that cutting down the amount of his food might bring about improvement. In 1908, Findlay, at the University of Glasgow, produced rickets in a group of puppies in laboratory cages on a milk and porridge diet. Inasmuch as another group allowed to run in the open did not contract rickets, he thought that muscular exercise was the explanation of the difference. In 1917, McCollum and Simmonds, studying the dietary deficiencies of the cereal grains, observed that many rats developed beaded ribs and other skeletal deformities, and they tried all sorts of changes in the mineral content of their rations to prevent these abnormalities of the skeleton which so strongly suggested rickets. They said that the diet was the sole determining factor in the etiology of the lesions in question, for the entire colony of approximately 2,000 animals lived under identical conditions except for those related to the composition and source of their food.



(Courtesy of Professors H. Steenbock and E. B. Hart)

Fig. 84. A Rachitic Puppy

While these observations were being made in Baltimore, Mellanby in a research conducted for the Medical Research Council of Great

Britain succeeded in inducing rickets in puppies by means of various faulty diets, such as bread or other cereal food with a little whole milk; or bread and a little separator milk, with linseed oil to replace the milk fat. When cod liver oil was substituted for other fat in the rachitic diet, the disease was prevented; since cod liver oil was by that time (1919) known to be rich in vitamin A, Mellanby concluded that this vitamin must be antirachitic as well as growth-promoting.

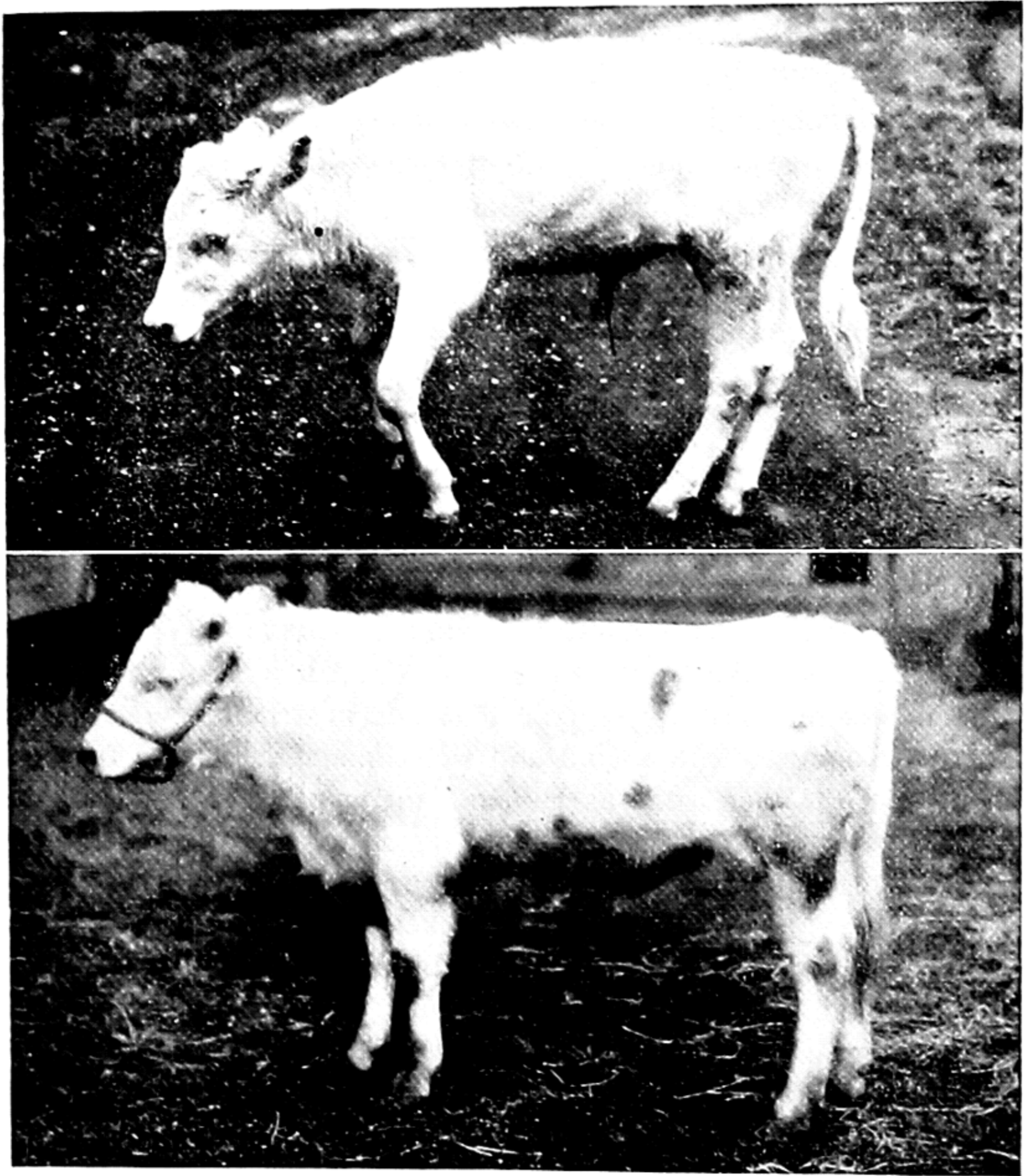
Inasmuch as rickets is a disease in which the bones are deficient in calcium, the very natural notion was widespread that administration of calcium should cure it. However, dosage with calcium generally gave disappointing results and rickets sometimes developed when children were fed liberally on cow's milk, rich in calcium. In 1921, Sherman and Pappenheimer threw light on this anomalous situation from another angle. They reported that rickets could be speedily induced in rats by the use of a diet lacking cod liver oil, high in calcium, and low in phosphorus; and that this rickets-producing diet could be changed to an antirachitic one by the simple addition of a suitable amount of a phosphorus salt.

A little later the Johns Hopkins investigators, having also succeeded in evolving a rickets-producing diet low in phosphorus, made the further observation that butter fat, while preventing the disease which results from shortage of vitamin A, did not satisfactorily modify the pathological condition of the skeleton; "if anything, it was intensified, probably as a result of the slight stimulation given by the butter fat to the growth of the bone."

On the other hand, when cod liver oil was added to the diet there were no signs of rickets. Within the year (1921) this difference between butter fat and cod liver oil was explained. Hopkins had pointed out in 1920 that if oxygen were allowed to pass through a heated fat any vitamin A which it contained would be destroyed, and very shortly McCollum in Baltimore, Steenbock in Madison, and Coward and Drummond in London reported that cod liver oil so treated lost its growth-promoting power but retained its antirachitic property. The vitamin was recognized as a substance distinct from vitamin A by McCollum and his associates in 1922 and given the name vitamin D.

Rickets and Sunlight

In the earlier clinical studies of rickets, two theories as to its cause were common; one that it is primarily a dietetic disorder, the other



(Courtesy of Professor E. B. Hart)

Fig. 85. A fall-dropped calf, nursed six months by the mother, given a concentrated ration including corn, bran, and linseed meal, and hay of low quality which was also fed the mother. A little out-of-doors exercise was allowed in the early morning. This animal was brought to the Wisconsin Agricultural Experiment Station in June, appearing as in the upper photograph. The deficiency of vitamin D was manifested by reduction in growth, by stiffness, and by deformity of the bones.

The lower photograph shows the same calf six months later, after treatment with 40 cc. of oxidized cod liver oil per day as a source of vitamin D.

that hygienic conditions, especially lack of sunlight, overcrowding, poor ventilation, and prolonged indoor confinement of infants in the winter time are the chief contributing factors. In 1890, Palm, an English physician practicing for some years in Japan, became interested in the geographical distribution of rickets, being struck with its absence in Japan "as compared with its lamentable frequency among the poor children of the large centers of population in England and Scotland." He had read the report of a committee of the British Medical Association published in 1889, which called attention to its great frequency in large towns and thickly peopled districts where industrial pursuits are carried on and to its specially great prevalence in the industrial zone between the Firth of Clyde and Firth of Forth. In Glasgow it was almost universal, and in London the situation was not much better. Palm had also read Hirsch's *Handbook of Historical and Geographical Pathology* (1886) in which it was said of rickets, "In amount and severity of type it stands in a definite relation to climate. Countries with a cold and wet climate, subject to frequent changes of weather, such as Holland, many parts of England, the north German plain, the mountainous regions of central and southern Germany, and the plains and mountainous districts of northern Italy, if they are not the exclusive seats of rickets are at all events its headquarters." He sent out a questionnaire to various medical missionaries in China and Thibet because he thought, "If we find the disease to be unknown where the diet and sanitary surroundings are even worse than in places where the disease prevails, we can no longer regard them as prime factors in producing the disease."

The reports, mostly from rural regions, told of poverty, of poor food, of filthy streets, and utter absence of sanitation, but no rickets. The air was generally dry and stimulating, with much sunshine, people living out of doors, the children practically naked and rarely weaned before three years of age. Palm suggested as a result of his study that "sunlight is essential to the healthy nutrition of growing animals and that a deficiency of it characterizes the localities or conditions of those who suffer from rickets and is the most important element in the aetiology of the disease."

Dick in his book on rickets (1922) stated that 80 per cent of the children in the London County Council schools had rickets and Plimmer called attention to the fact that the proportion of men rejected following World War I as army recruits on the ground of

physical unfitness corresponded with this earlier estimate of the percentage of children in London schools suffering from rickets.

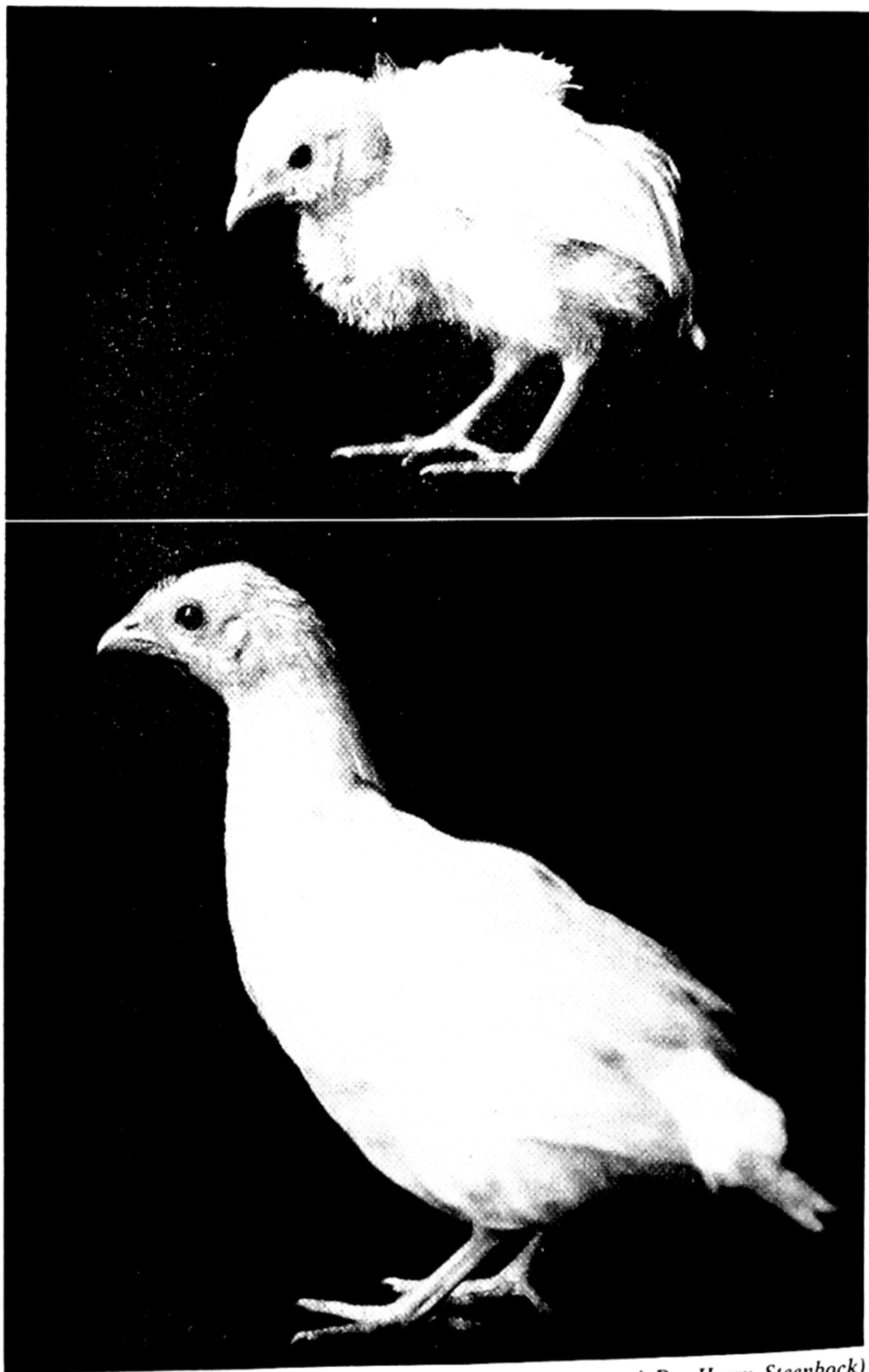
Refined methods of diagnosis were made possible by use of the X-ray and many children who would not have been classified as rachitic by the earlier clinicians were added to the list of the afflicted. Hess and Unger found that fully three-fourths of the bottle-fed and half the breast-fed babies of New York City showed at least slight signs of rickets in March, the time of year when the disease reached its peak. In New Haven, Eliot in a study sponsored by the United States Children's Bureau and the Pediatric Department of the Yale School of Medicine, found that 179 out of 216 infants examined (83 per cent) showed evidence of mild rickets by X-ray examination before eight months of age.

In 1921 it was demonstrated by Hess, Unger, and Pappenheimer in New York and by Shipley, Park, Powers, and McCollum in Baltimore that the development of rickets in rats fed a standard rickets-producing diet could be prevented by daily exposure to direct sunlight, and Hess and Unger found further that the low inorganic phosphate characteristic of the blood serum of rachitic infants could be raised to the normal level by daily sun baths. Thus the strong belief of many that hygiene plays a significant role in rickets was confirmed, and the irregularity with which rickets occurs in the same community explained.

It did not take long to discover through studies on young children that there is a seasonal tide of blood phosphorus which is directly related to the amount of sunshine at different times of the year. This led to the application of "artificial sunlight" by means of a carbon arc lamp similar to that employed in taking motion pictures, and to the realization that it is the short rays known as the ultra-violet which are curative of rickets. The fact that these shorter rays do not penetrate dark clothing or pigmented skin explained further some of the irregularities in the occurrence of rickets, especially the high susceptibility of Negro infants.

Light and Vitamin D

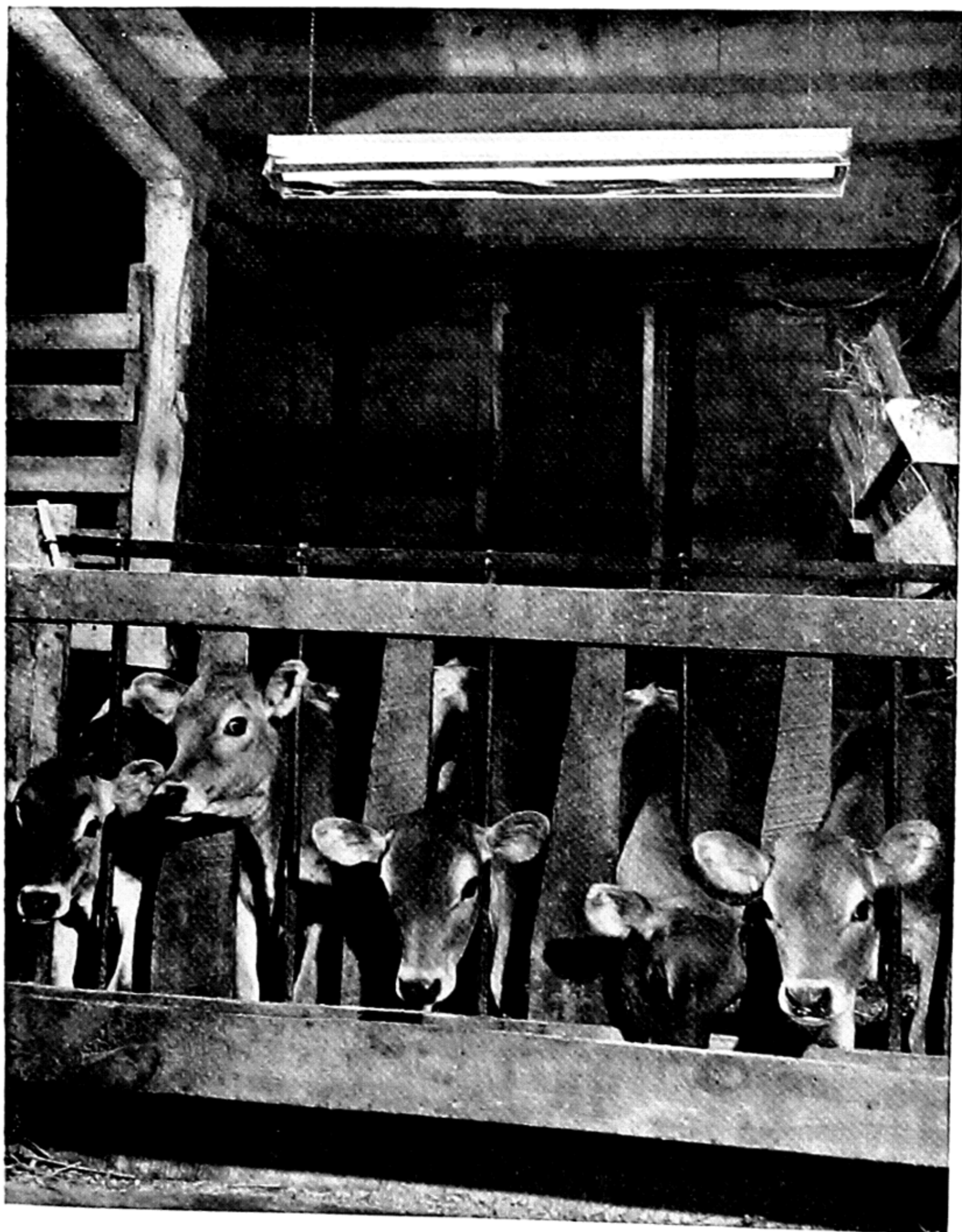
How the same effect could be secured by such diverse agencies as (1) direct sunlight, (2) cod liver oil, (3) a ration carefully balanced with regard to calcium and phosphorus, and (4) ultra-violet light was a mystery. The solution was found in 1924 when almost simul-



(Courtesy of Dr. Harry Steenbock)

Fig. 86. These two chicks are the same age and were fed the same diet, but the upper one was kept in a dark room, while the lower had plenty of sunshine.

taneously Hess in New York and Steenbock and Black at the University of Wisconsin showed that liver, lung, and muscle tissue from irradiated rats would promote bone calcification in rachitic rats while that from nonirradiated rachitic animals would not do so. The irradiation of food was tried next, and it was found that cottonseed



(Courtesy of Westinghouse Electric Corp.)

Fig. 87. Young Calves Share the Benefits from a Modern Sun Lamp

and linseed oils could thus be made antirachitic but mineral oil (which is not fat) could not, and that in general only those foods could be irradiated successfully which contained true fat.

As fast as possible, all sorts of material were irradiated and tested. The success of irradiation was found to depend not on the fat present in the food, but on another substance occurring in minute quantity in the oils of seeds including cereal grains and in vegetable oils such as olive, peanut, and cottonseed, known as phytosterol; or in a closely related substance in animal fats called cholesterol. The chemical search for the pure vitamin in activated cholesterol led to



(Courtesy of Distillation Products, Inc., Rochester, N. Y.)

Fig. 88. Crystals of Vitamin D₂

a further surprise. The substance which could be most effectively activated proved to be another chemically related substance associated with cholesterol, called ergosterol, then little known and sup-

posed to have no biological significance. It is found in largest amounts in ergot, from which it gets its name, and in yeast.

Pure ergosterol was irradiated and found to have a vitamin D activity 200,000 to 700,000 times that of cod liver oil. It is curative for rats in doses of 0.0001 milligram. The identification of ergosterol as a substance from which vitamin D can be made was announced in 1927 by Rosenheim and Webster and also by Windaus and Hess. Irradiated ergosterol was promptly made available to the public as a concentrated solution in oil known in this country as viosterol, usually prepared so as to have a potency in rat units about 250 times that of a standard cod liver oil.

Activated ergosterol was found to contain at least half a dozen substances. It was "a complex resinous mixture" resisting all efforts at crystallization. Finally in 1930 Bourdillon, with Askew and other associates at the National Institute for Medical Research in London, was able to produce small amounts of a crystalline substance which he named calciferol, protective for a rat in doses of 0.000005 milligram. Later further purification was reported and twice as great antirachitic potency. Meanwhile Windaus, who at the University of Göttingen had engaged in the study of cholesterol for many years, was also giving his attention to the search for pure vitamin D and in 1931 reported the isolation of two crystalline substances protective for a rat in dosage of about 0.000003 milligram, one of which was subsequently identified as the calciferol of the English investigators, now known as vitamin D₂. The other was the same substance in combination with another which was physiologically inactive. Pure calciferol has an antirachitic potency of 40,000 International Units per gram.

Further investigation revealed that not only ergosterol and cholesterol but other closely related compounds could be made antirachitic by irradiation. Tests on chicks and rats showed that a dose ample for one might be too small for the other. Gradually it became apparent that vitamin D is not a single substance, but a group of closely related compounds. New compounds with vitamin D activity have been developed in the laboratory, so that many are now known to the chemist. The two most important forms are those known as vitamin D₂ (calciferol) and vitamin D₃ (a form obtained from fish liver oil). The latter is believed to be the form which is produced when the skin is irradiated with ultra-violet rays.

The Prevention and Cure of Rickets

Although rickets is a disease affecting the whole body, its most characteristic symptom is a failure of the bones to calcify properly, with resulting deformities. The first defect to appear is the so-called "rachitic rosary"—a row of beadlike protuberances down each side of the chest where the bones of the ribs join the costal cartilages (Figs. 89 and 90). The chest fails to develop normally, the ribs are



(Courtesy of Norman Jolliffe, M.D.)

Fig. 89. A Case of Rachitic Rosary in an Infant

thrust forward, forming a pigeon breast, and the lung space is contracted, interfering with deep full respiration. The ends of the long bones become enlarged, especially at wrists and ankles. Calcium phosphate is not deposited in the normal way. The evidence of rickets is seen at the junction of the shaft of the bone with its head, called the epiphysis. In the normal bone this junction is a straight, clear line; in the rachitic bone it is ragged if not wholly obscure. The cartilage of the epiphysis is not converted into bone, but persists and increases,

and there is an irregular enlargement of the soft tissue. The lacelike bony structures in the end of the shaft, called trabeculae, are poorly developed, giving further signs of the inability of the body to store calcium and phosphorus. They are normal reservoirs of calcium and phosphorus where any surplus is stored and from which these elements are withdrawn if needed elsewhere.

A normal calcium and phosphorus metabolism depends upon many factors, especially (1) the ability of the body to absorb these minerals from the food; (2) the supply of enough of each element to meet the requirements of growth; and (3) the amount of vitamin D supplied. Since calcium and phosphorus are the materials upon which the growth and maintenance of normal bone so largely depend, it is easy to see that calcium and phosphorus must be furnished in sufficient amounts to get the best results. In the case of the rat, suitable

proportions of these elements seem to be more important than a large amount of vitamin D in avoiding rickets, but in human beings liberal vitamin D is essential to the best utilization. Normal infants on a diet of milk, even when showing no symptoms of rickets, retain more calcium and phosphorus from the food and grow better if



Fig. 90. Rachitic Rosary in the Rat Resulting from a Vitamin D-Deficient Diet

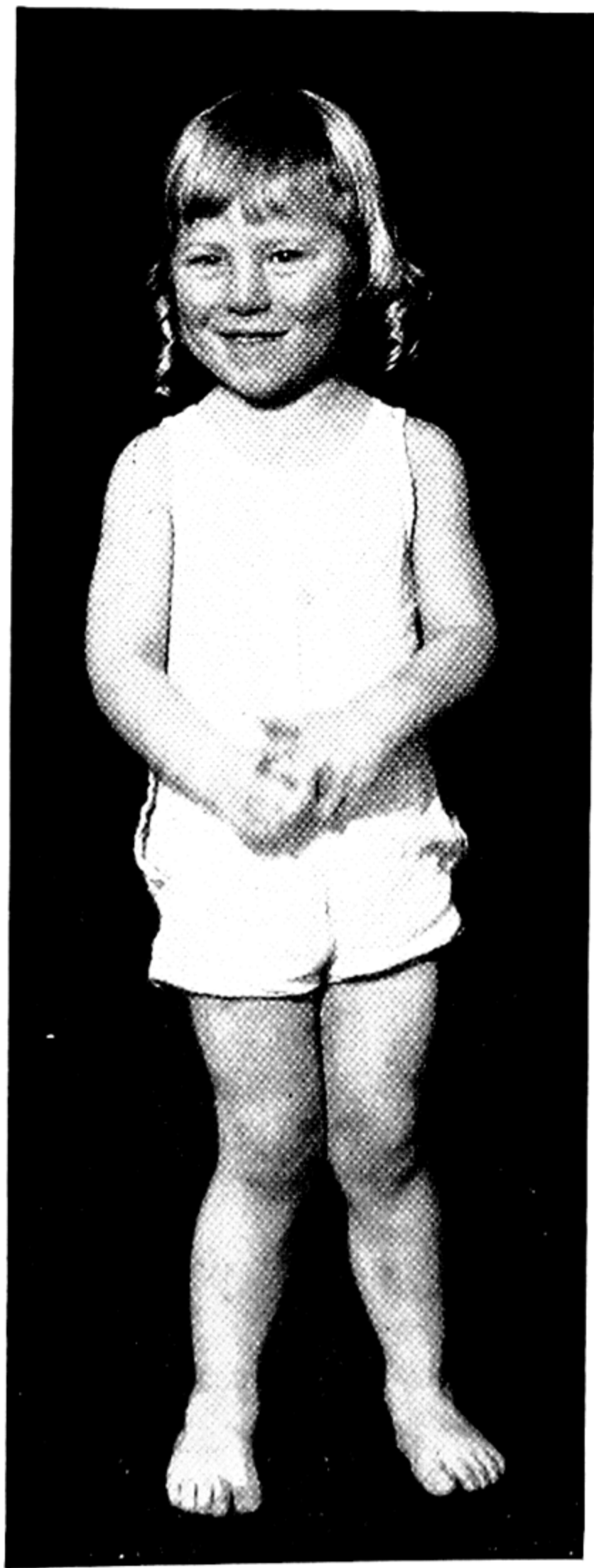
given additional vitamin D. Thus Daniels and some of her associates at the Iowa Child Welfare Research Station found that giving vitamin D to babies on milk formulas increased the phosphorus retention

to three or four times what it had been on the milk only, and calcium retention was also very markedly improved. It is very evident that in human beings vitamin D helps to conserve calcium and phosphorus even when both are fed in the liberal amounts and good proportion in which they occur in milk.

The best diet to prevent or cure rickets is one in which liberal calcium and phosphorus are kept in favorable relationship by a moderate but regular supply of vitamin D, either directly, through the action of the ultra-violet rays of sunlight upon the skin, enabling the body to manufacture its own; through the use of some food naturally rich in the vitamin, such as halibut, cod, or other fish liver oil; or through the use of a food which has been fortified by irradiation or by adding a vitamin D concentrate. The latter may be prepared from fish liver oil or by irradiation of ergosterol.

The Development and Health of the Teeth

That vitamin D plays an important role in the prevention of dental caries was demonstrated by McBeath and Zucker¹ of Columbia University in a study extending over four years in nine



(Courtesy of Dr. Ulysses C. Moore)

Fig. 91. A Case of Mild Rickets Resulting in Knock-Knees

different orphanages in and near New York City. The subjects, over

¹ McBeath, E. C., and Zucker, T. F. "The Role of Vitamin D in the Control of Dental Caries in Children." *The Journal of Nutrition*, Vol. 15, page 547 (1938).

800 in all, ranged in age from six to fourteen years. It was established that the incidence of dental caries was seasonal, the greatest number of new cases appearing in late winter and early spring and the smallest number during the summer. Giving graded amounts of vitamin D (as vitamin D milk, in which the vitamin D was of animal origin) resulted in graded prevention. Of the three amounts given (250, 400, and 800 International Units daily) only the highest entirely prevented an increase in new cases of caries during late winter and early spring. The two lower dosages had significant effects, however, with more protection resulting from the use of 400 units than of 250. When these investigators tried improving the diet by simply adding protective foods or increasing the amount of ordinary milk in the diet, no other source of vitamin D being given, they found some reduction in new cases of caries but not equal to that seen when the vitamin D milk was given. When they reversed the control and experimental groups during two successive years in 100 cases, they found the results reversed, indicating, they thought, that "individual susceptibility to caries was negligible compared to the effect of nutritional factors."

Of interest in connection with these findings are those of East and his associates² who, using data on the incidence of dental caries in children collected by the American Dental Association and the United States Public Health Service along with the records of the United States Weather Bureau giving the annual hours of sunshine in the localities in which the children lived found that in the regions where the hours of sunshine were highest the number of cases of caries in every instance was lowest. Also they found that groups living in zones which had an average winter temperature below 30° Fahrenheit had higher incidence of caries than those living where the mean winter temperature was higher, and, in accord with this, the children living in the north showed more caries than those living in the south.

Pregnancy and lactation make such heavy demands upon the mother that there is some basis in fact for the old saying "a tooth for every child." For tooth protection there is certainly need for

² East, B. R. "Mean Annual Hours of Sunshine and the Incidence of Dental Caries." *American Journal of Public Health*, Vol. 29, page 777 (1939). East, B. R., and Kaiser, H. "Relation of Dental Caries in Rural Children to Sex, Age, and Environment." *American Journal of Diseases of Children*, Vol. 60, page 1289 (1940).

liberal supplies of calcium and phosphorus with sufficient vitamin D to insure their fullest utilization. Park,³ a well informed and conservative pediatrician, called attention to the importance of the diet of pregnant women in the following words: "Personally, I believe that if pregnant women received ample well balanced diets, in which green vegetables were abundantly supplied and cow's milk was regularly taken, and they were kept a sufficient part of their time in the open air and sun, and their infants were placed in the direct rays of the sun for a part of each day and were fed cod liver oil for the first two or three years of life, more could be accomplished in regard to the eradication of caries of the teeth than in all other ways put together and that rickets would be abolished from the earth."

Experimental Tooth Defects

The molar teeth of rats strongly resemble those of human beings, and much study has been devoted to the production by dietary means of tooth defects in these animals, since the first caries were thus produced by McCollum and Grieves in 1922, by disturbing the calcium-phosphorus ratio of the diet and giving insufficient amounts of "fat soluble vitamin" (A and D). It is possible to induce caries in rats' teeth by means of a calcium-free diet, but as long as vitamin D is furnished, the calcium of the skeleton is drawn upon to maintain the normal metabolism, and this reserve must be well exhausted before caries will develop. On a diet high in calcium, very low in phosphorus, and lacking vitamin D, severe rickets is quickly induced, and caries develop rapidly. In the case of children, the fact that rickets and caries develop on a diet in which cow's milk is prominent, affording liberal calcium and phosphorus, indicates that shortage of vitamin D is more serious than in the case of the rat, an animal designed by nature to live in darkness.

Lady May Mellanby observed that when Sir Edward Mellanby's puppies developed rickets their teeth were seriously affected, and began an investigation of the factors controlling normal tooth development in dogs. She found that young puppies fed diets lacking in vitamin D showed delay in the eruption of the permanent teeth; the enamel was irregularly formed and poorly calcified, the surface being

³ Park, E. A. "Certain Factors Causing the Deposition of Lime Salts in Bone." *Dental Cosmos*, Vol. 65, page 176 (1923).

pitted and grooved; the jaw bones were thickened and the teeth irregularly arranged. The dentine also was irregularly calcified, and the tissue at the margin between tooth and gum was abnormal in its development.

In 1927, the Medical Research Council of Great Britain, greatly impressed by Lady Mellanby's findings on dogs, decided to support her in an investigation of the effect of vitamin D on the teeth of children. Three institutions in the neighborhood of Birmingham were chosen, caring for 835 children from two and one-half to sixteen years of age. At one of them there was added to the diet $1\frac{1}{2}$ ounces daily of syrup (treacle); at another, $1\frac{1}{2}$ tablespoons of olive oil; and at the third, the children under eight years of age each received 1 tablespoon of cod liver oil, and those who were older, $1\frac{1}{2}$ tablespoons. Thorough dental examinations were made every six months for two years. At the final inspection it was found that while the actual number of carious teeth had approximately doubled at the institutions where syrup and olive oil were fed, it had increased by only one-half in the third, where cod liver oil was given.

It would thus appear that in England, where rickets has been rife for centuries and where the climate continues to foster the disease, lack of vitamin D is the primary cause of dental defects, but in this country, where rickets is mild, and in tropical countries where it is nonexistent, other factors must be sought to explain the widespread distribution of dental caries.

Diets low in calcium, phosphorus, and vitamin D have been shown both clinically and experimentally to be unfavorable to normal tooth development and to their health throughout life. A tooth is never inert; it is liable to lose its mineral salts at any time when conditions become unfavorable for their conservation, just as its odontoblasts, upon which its nutrition so directly depends, become disorganized when ascorbic acid is lacking; and as the attaching soft tissues lose their normal character and become spongy and inflamed when either vitamin A or ascorbic acid is deficient.

Various experiments with children's diets in relation to dental caries suggest that teeth are either very delicate indicators of deficiencies not readily detectable or that there are factors in foods affecting teeth which are still unknown. Diets which include daily a quart of milk, an egg, an orange, a teaspoonful of cod liver oil, an ounce of butter, and two or more servings of succulent vegetables

and fruits, have been found to cause definite improvement in the teeth of children supposed to have been well fed. Until further investigations shall be made, in which only one dietary factor is varied at a time, it is impossible to know the relative importance of all the factors which certainly influence tooth health.

It appears to be well established that defects in tooth structure do occur in rickets although they may be difficult to distinguish from injuries caused by deficiency of vitamin A or ascorbic acid. In children suffering from rickets dentition is commonly delayed.

Measurement

The measurement of vitamin D is achieved by tests on laboratory animals. Rats and chicks are both used, but the standard test adopted by the United States Pharmacopeia is made with rats. It is necessary to make newly weaned animals severely rachitic rather quickly and this is accomplished by feeding them a standard rickets-producing diet. The degree of rickets induced may be determined by analyzing one leg bone to see how the calcium content compares with that of a normal animal or by what is commonly called the "line test." The "line" is one of freshly deposited calcium phosphate across the head of a long bone which can be distinctly seen under the microscope when the bone is cut and suitably stained (Fig. 92). The potency of the material to be tested is determined by comparing the degree of healing caused by it with that resulting from feeding a known quantity of the standard reference material to a similar group of animals kept under the same conditions.

The international standard reference material for vitamin D, adopted by the World Health Organization in 1949, is pure vitamin D₃. The International Unit (I.U.) is defined as the vitamin D activity of 0.025 microgram of this standard. The United States Pharmacopeia unit is identical with the International Unit.

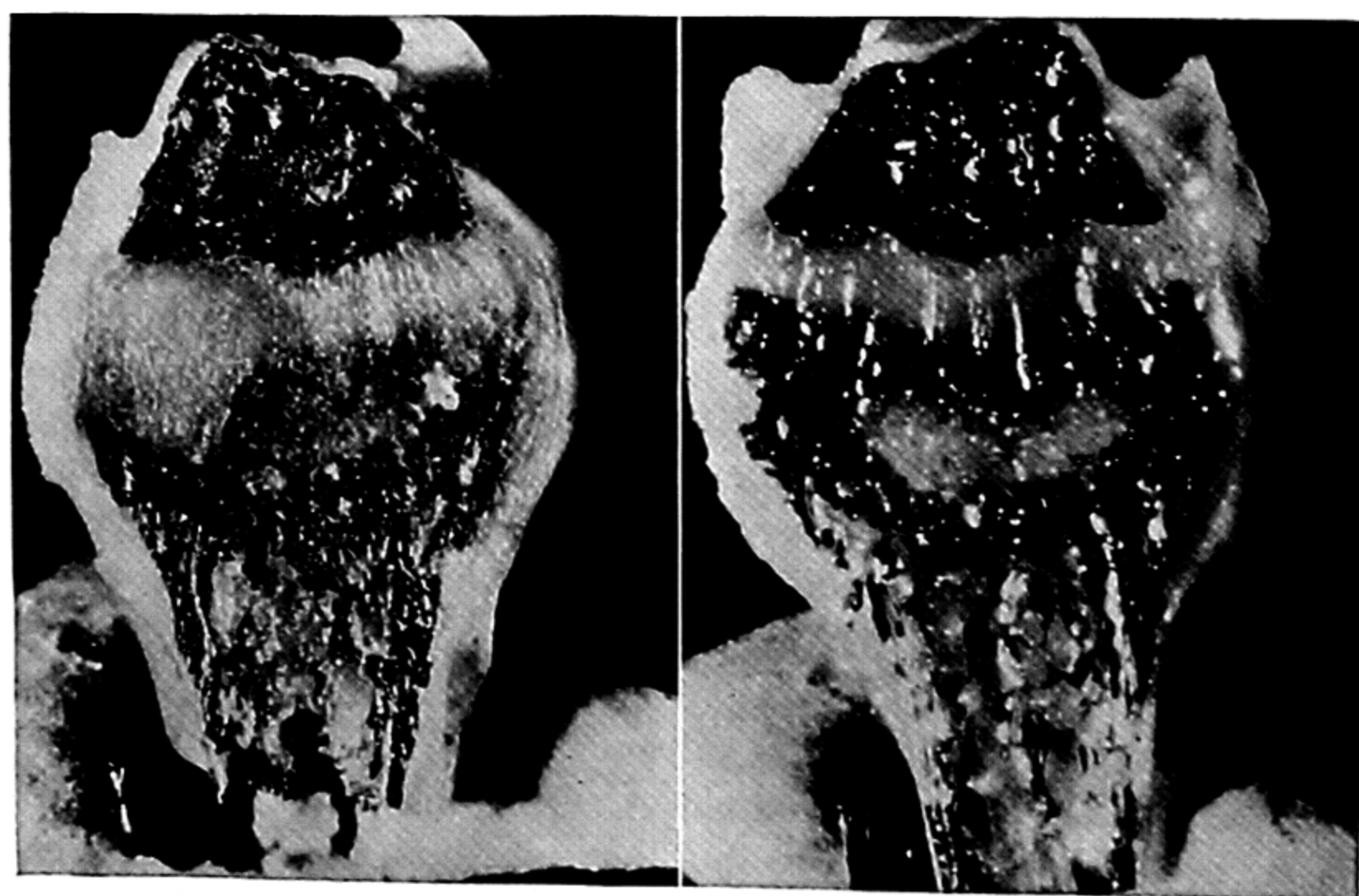
Sources

Leaving out of consideration the production of vitamin D within the living body by the direct action of sunlight upon the skin, or by the action of artificial sunlight from the carbon arc lamp, or by that of the ultra-violet rays from the mercury quartz vapor lamp, this discussion will be confined to the occurrence of vitamin D in natural foods and in other food materials in which it has been produced or increased by artificial means.

Fish liver oils are the richest natural sources of this vitamin. The yield of some of them is shown in the table below:

APPROXIMATE AMOUNTS OF VITAMIN D IN SOME
FISH LIVER OILS

<i>Fish Liver Oil</i>	<i>International Units per Gram</i>	<i>International Units per Teaspoon</i>
Bluefin tuna	40,000	180,000
Swordfish	10,000	45,000
Yellowfin tuna	10,000	45,000
Black sea-bass	5,000	22,500
Rockfish	1,400	6,300
Chinook salmon	1,300	5,850
Halibut	1,200	5,400
Boston mackerel	750	3,375
Pufferfish	570	2,565
Turbot	260	1,170
Cod	100	450
Haddock	10	45



(Courtesy of E. R. Squibb & Sons)

A

B

Fig. 92. Lengthwise Sections of Leg Bones (A) of Rat with Rickets, and (B) Showing Line of New Bone Formed Following Administration of Vitamin D

No other type of food can compare with fish liver oils as a source of vitamin D. The body oils of many fish also furnish considerable amounts, the entire body oil of the herring yielding as much per gram

as cod liver oil, that of the sardine about four-fifths as much. Of foods common in the American dietary other than fish, egg yolk and liver (beef, chicken, hog, etc.) are richest in vitamin D, the amounts depending, however, on the diet of the animal. Eaten regularly by children, eggs may turn the tide against rickets if the amount of vitamin D derived from sunshine is not too small. Casparis, Shipley, and Kramer were able to demonstrate definite healing in seven colored children upon adding to a diet of cereal and milk one or two eggs daily.

Cow's milk has naturally a low concentration of vitamin D and since it plays such an important part in the diet, the practice of increasing the vitamin D content provides a desirable safeguard for children. Enrichment of milk in vitamin D need not add materially to the cost and will insure to all using milk in liberal amounts a regular supply of vitamin D. A large amount of the evaporated milk now on the market is irradiated, and vitamin D fluid milk is now available in many localities. Commonly vitamin D milk contains 400 I.U. of the vitamin per quart.

The higher plants do not require and do not produce vitamin D. Only one natural plant source has been discovered. This is an alga which grows at shallow depths in the Caribbean Sea, known as the Sargassum weed. Oils of this plant have been found curative for rickets in rats.

For babies and growing children, and probably for adults, too, the regular supplementing of the ordinary diet, however rich it may be in milk, butter, and eggs, with some especially good source of vitamin D during the periods of the year when exposure to clear bright sunlight is difficult, should become a routine practice. Cod liver oil is a source which has proven successful in a great variety of circumstances, and it has the advantage of furnishing at the same time the equally desirable vitamin A. Other fish liver oils on the market are percomorph and halibut liver oils, both richer in vitamins A and D than cod liver oil. The percomorph oil is so much richer than cod liver oil that only a drop or two needs to be taken. The table below gives the vitamin D values of some common foods.

Irradiated ergosterol dissolved in a small amount of oil is standardized as to its vitamin D content and sold as viosterol. A few drops daily are sufficient to protect a baby against rickets, but it should be remembered that viosterol furnishes none of the vitamin A also

important for the best development. It has been found that to cure infantile rickets relatively higher levels of vitamin D from viosterol than from cod liver oil are necessary.

VITAMIN D VALUES OF THE EDIBLE PORTION OF SOME COMMON FOODS

<i>Food</i>	<i>I.U. per 100 Grams</i>	<i>I.U. per 100 Calories</i>	<i>Food</i>	<i>I.U. per 100 Grams</i>	<i>I.U. per 100 Calories</i>
Butter	80	11	Liver		
Cheese, Cheddar	33	8	Beef	45	35
Clams, long	6	8	Calf	15	12
Cream			Chicken	50	39
Thick	20	5	Hog	45	35
Thin	10	5	Lamb	20	16
Eggs			Milk		
Dried, commercial	220	40	Dried	16	3
Whole	50	34	Evaporated	5	4
Yolk	150	44	Fresh, whole	2	3
Fish			Vitamin D	41	60
Herring	1,200	840	Oysters	5	6
Mackerel	1,100	792	Shrimp	150	183
Salmon					
Pink	600	294			
Red	800	392			
Sardines, canned	600	288			

During recent years many new vitamin D preparations have been put on the market. One must rely upon the statements on the container as to the potency of the product. Care should be taken in using vitamin D preparations since too large dosages can be toxic.

Requirement

A vast amount of experience both with human beings and laboratory animals now attests the importance of vitamin D for the prevention of rickets and other allied diseases of the bones and for the best development of the skeletal tissues including the teeth. The amount of vitamin D needed to supplement that naturally formed in the body must vary greatly with climate, season, and mode of life. There is no way at present of measuring accurately the amount of vitamin D formed in the human body by the action of ultra-violet light. There is also a great deal of variability in the vitamin D content of natural foods. Although the vitamin D requirement depends on many factors, practical experience with infants in this country under

controlled conditions has given us knowledge of what amounts of cod liver oil are likely to be protective for most infants on otherwise adequate diets in our climate and under our living conditions.

Jeans and Stearns,⁴ as the result of a careful evaluation of all the literature on this subject, concluded (1) that the normal artificially fed baby probably requires between 300 and 400 units daily; (2) that while normal breast fed babies doubtless require less than the artificially fed, nevertheless, it would seem to be a desirable measure of protection to give them the same amounts as the artificially fed infants; (3) that prematurely born babies may very well be given twice as much as the normal infant during the period of most rapid growth and thereafter the same amount as normal infants; (4) that for children between infancy and adolescence the allowance should be 300 to 400 units of the vitamin along with a pint and a half of milk, for the sake of assuring desirable retention of calcium and phosphorus; (5) that adolescents should have as much as infants.

Jeans believed that vigorous adults leading a normal life have minimum need for supplementary vitamin D, but that for night workers and others whose mode of life shields them from sunlight, as well as elderly persons, small supplements of the vitamin are desirable. He called attention to the fact that osteoporosis occurs commonly in the elderly. The cause of this is not known. Until it is established a small supplement of vitamin D may be a wise precaution.

It is well known that the need for calcium and phosphorus is greatly increased during pregnancy and lactation. Supplementary vitamin D will increase the utilization of these mineral elements. The optimum amount is not known as yet, but the evidence reported thus far indicates that 400 I.U. daily is probably an adequate dosage. The recommended allowances of the Food and Nutrition Board will be found in Table III(a) in the Appendix.

The requirement of poultry and stock animals for vitamin D has been actively investigated and various preparations of the vitamin are now added to the feeds for these animals. The regular use of such preparations in their feeds has been found to increase egg production from a seasonal to a year-round basis and has made milk production more uniform throughout the year.

⁴ Jeans, P. C., and Stearns, G. "The Human Requirement of Vitamin D." *The Vitamins*, Chapter 27. American Medical Association (1939).

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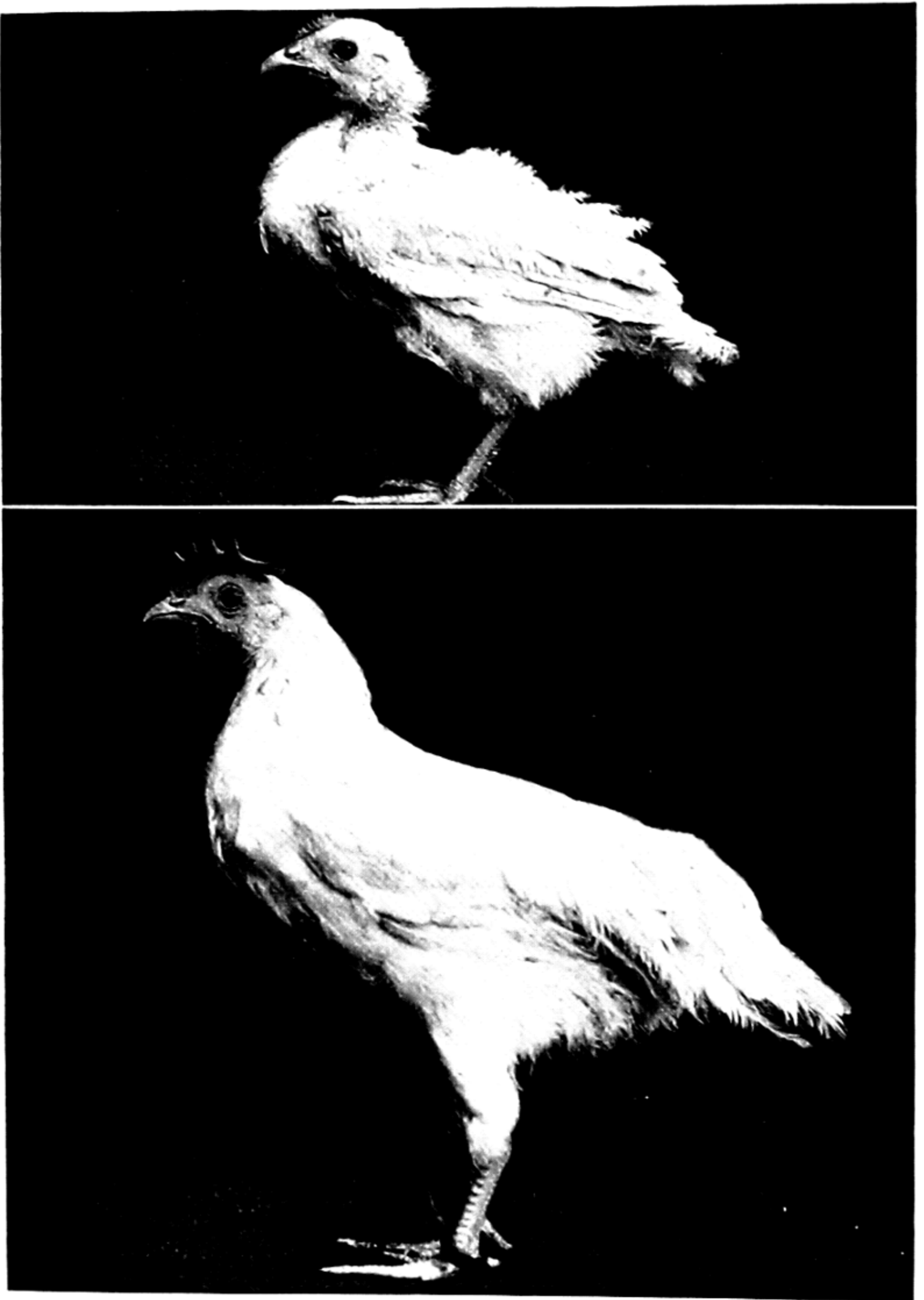
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Riboflavin

Discovery

Many irregularities in the behavior of foods containing "water-soluble vitamin B" engendered skepticism as to whether all the properties attributed to vitamin B really belonged to a single vitamin. By 1919 the assumption that vitamin B was a single substance both antineuritic and growth promoting was being definitely challenged, and a little later it was shown that when yeast was heated for two hours under pressure (autoclaved) its power to cure polyneuritic pigeons was destroyed, yet it could still stimulate growth in a rat. For several years reports of this kind became increasingly common. For example, it was found that rats would not grow normally if a large amount of rolled oats were the only source of vitamin B. Yet the addition of only a little (5 per cent) of brewer's yeast, heated till it would no longer cure polyneuritis in a pigeon, brought about normal rat growth. It was quite apparent that the autoclaved brewer's yeast added something necessary for the rat which the oats lacked. Another interesting experience of this same period (1926) was with regard to corn as the only source of vitamin B for chicks. With as much as 30 per cent of whole corn in the ration, polyneuritis was prevented but growth was very poor; but if one-third of the corn were replaced by dried brewer's yeast, excellent growth resulted. The difference in the chicks on the two rations is shown in Fig. 93.

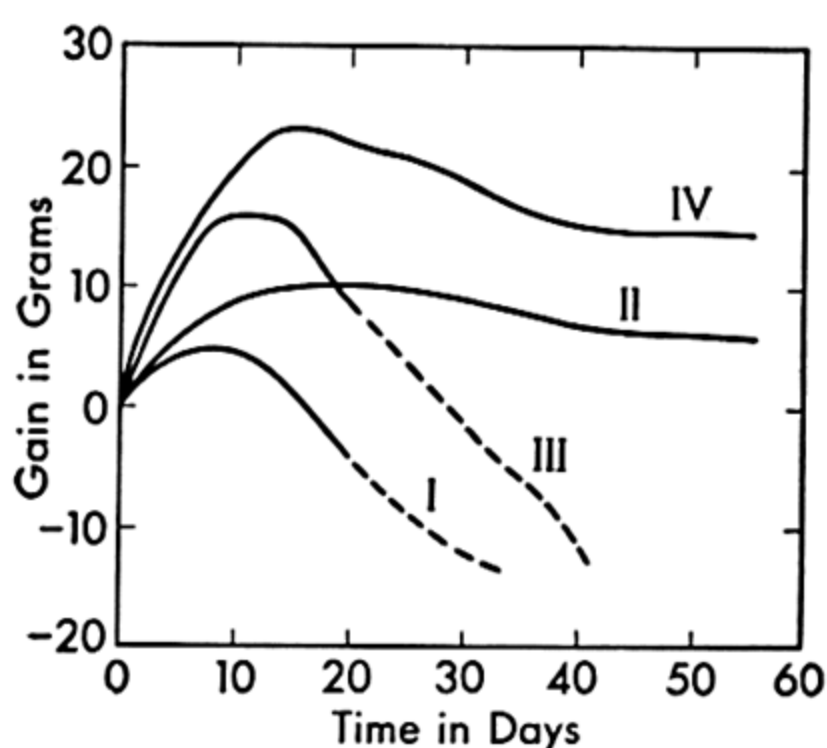
It took some time for investigators to perceive the full significance of such findings, but an experiment by Sherman and Axtmayer in 1927 helped to clear the confusion resulting from varying results with heated (autoclaved) and unheated yeast, and from using dif-



(Courtesy of Drs. S. M. Hauge and C. W. Carrick)

Fig. 93. The upper chicken was fed from hatching for ten weeks on a diet containing 30 per cent of corn. It showed no symptoms of polyneuritis but failed to grow well, and attained a weight of only 200 grams. The lower chicken was fed the same diet as the one above, except that one-third of the corn was replaced by an equal weight of dried brewer's yeast. The combination resulted in normal growth and a final weight in 10 weeks of 485 grams, showing that two vitamins were involved.

ferent kinds of food as the source of vitamin B. They fed one group of rats a vitamin B-free diet to which 0.8 gram daily of ground whole wheat was added, and no growth resulted. They fed another group the same amount of autoclaved yeast with no more success. To a third group of animals they gave 0.8 gram of a mixture of the two in equal parts. The result was much better growth, as shown in Fig. 94. It was evident that each food material furnished something the



(Courtesy of Drs. H. C. Sherman and J. H. Axtmayer)

Fig. 94. Growth Record of Rats Showing Supplementary Effects between Whole Wheat and Autoclaved Yeast

- I. Failure to grow on a diet free from vitamins B and G.
- II. Practically stationary weight when 0.8 gram daily of ground whole wheat was added (much vitamin B).
- III. Failure to grow when 0.8 gram of autoclaved yeast was added (no vitamin B).
- IV. Growth when 0.4 gram whole wheat and 0.4 gram autoclaved yeast were added. (The wheat furnished vitamin B; the yeast, vitamin G.)

other lacked for growth, or in other words that there were two different growth-promoting substances, one of which was antineuritic (the whole wheat) while the other (the autoclaved yeast) was not. A further test of skim milk as the source of both vitamins showed that milk was very effectively supplemented by whole wheat, which meant that it was not as rich in the antineuritic vitamin as in another growth-promoting one found in autoclaved yeast.

From these and numerous other researches it was established beyond doubt by 1928 that there was an antineuritic vitamin B (B_1) and another growth-promoting vitamin which was incapable of curing polyneuritis, designated vitamin G (also known as B_2). These two vitamins are now called thiamine and riboflavin, respectively.

Since thiamine in any extract could be destroyed by heating, such materials as yeast and milk, now known to be rich in riboflavin, were used as the source of concentrates for the chemical study of the vitamin as well as investigation of its nutritional properties. In the Department of Chemistry of Columbia University Bocher by

Riboflavin

1933 had achieved a high concentration of the vitamin from whey powder, so that the final product had 2,000 times the riboflavin activity of the original milk. It was adequate for growth when fed in conjunction with a concentrate of thiamine.

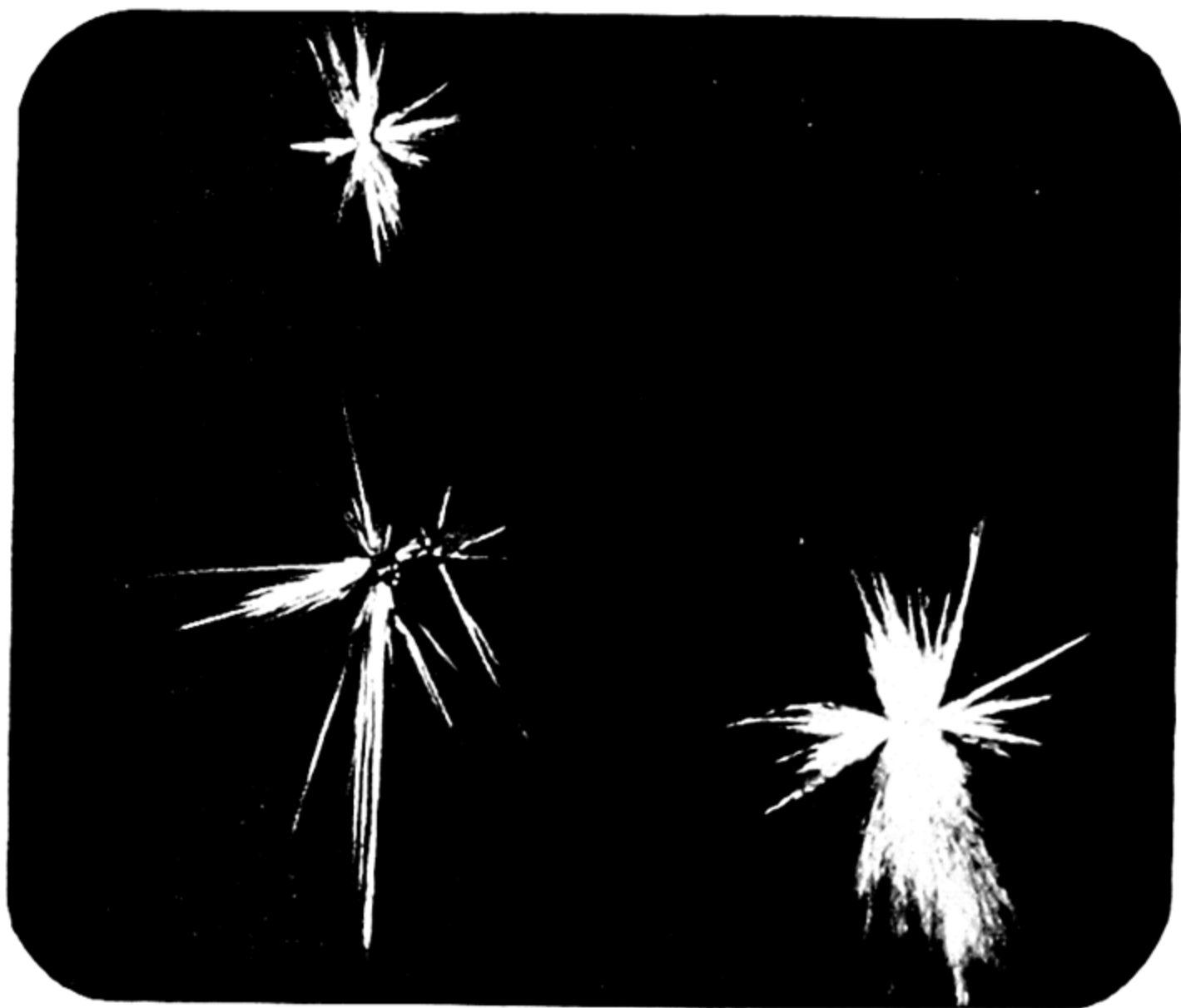
Meanwhile another line of investigation had opened new vistas for students of biological problems. It had been known since 1879 that there were in plant and animal tissues water-soluble, yellowish pigments having a greenish fluorescence, but no one had given any particular attention to their possible function. In 1914, in a paper from the University of Missouri, Palmer and Cooledge wrote: "The natural yellow color of cow's milk is caused by two entirely different kinds of pigments; the principal one of the two pigments is found in milk fat. It has recently been found by one of us to be a mixture of carotin and xanthophylls, principally carotin, which are transmitted to the milk fat from the green feeds of the cow. The secondary or minor pigment has not been identified. Its presence in the milk is largely masked by the white color of the caseinogen and is only seen in the whey which remains after the caseinogen has been coagulated. The pigment is then seen imparting the usual greenish color to whey."¹ The "carotin" we recognize, of course, as the carotene of today, the precursor of vitamin A. Little did these authors dream that both pigments were vitamins!

It was approximately twenty years later before the "lactochrome's" biological significance began to be understood. It was not until 1932 that Warburg and Christian at the Kaiser Wilhelm Institut, Berlin, reported some of their investigations of the "yellow oxidation enzyme" which plays an important part in cell respiration. The next year the yellow pigment was isolated from whey and egg white in pure crystalline form, 0.06 gram of crystals being obtained from about 750 gallons of milk, by Kuhn and others at the University of Heidelberg in Germany. Analysis showed that it belonged to a group of compounds known as flavins. These crystallize in yellow-brown needles which when dissolved in water give a yellow solution with a greenish-yellow fluorescence. According to the substance from which they were extracted they were called lactoflavin, ovoflavin, etc.

Along with the chemical studies went biological tests, and the fact that growth was stimulated by very small quantities suggested that

¹ Palmer, L. S., and Cooledge, L. H. "Lactochrome—The Yellow Pigment of Milk Whey." *Journal of Biological Chemistry*, Vol. 17, page 251 (1914).

it was a water-soluble vitamin belonging to the vitamin B group, but it would not with vitamin B₁ support growth in a rat unless something else present in yeast was added at the same time. This caused a little confusion at first, because Booher was able to get growth by adding her concentrate only, and yet the concentrate had



(Courtesy of Merck & Co., Inc.)

Fig. 95. Crystals of Riboflavin

the characteristics of flavin, the deep orange-red color and the yellowish-green fluorescence in a water solution. However, as she purified her material further, she, too, found that something was lost which was a factor in growth and that her concentrate plus pure crystalline thiamine also needed a supplement. She then decided that vitamin G was itself the water-soluble, yellow pigment or the pigment was an integral part of the vitamin. Subsequent work made it clear that what was at first thought to be a single vitamin was a mixture, of which this water-soluble, yellow pigment, vitamin G, was only one part. In 1935 the synthesis of riboflavin was accomplished almost simultaneously by Kuhn and associates in Germany and Karrer and associates in Switzerland.

The Promotion of Growth

Riboflavin is now known to be essential for the growth of all animals, the effect of a dietary deficiency of it having been extensively investigated. The failure to grow has been described as the primary effect of the restriction of riboflavin. It is an essential constituent of all active body tissues that have been examined and unless a minimum amount is present in the diet new tissue cannot be formed. The riboflavin enzymes are an important part of essential substances of muscle tissue which makes up a large portion of the total body composition. This helps to explain why in a riboflavin deficiency tissues retain their riboflavin so tenaciously and an animal does not show as rapid a loss in weight as in a thiamine deficiency.

Early studies on the growth of animals dealt with multiple deficiencies and were undoubtedly more like the deficiencies which we deal with in human nutrition where diets are generally poor and low in more than one vitamin. With pure crystalline vitamins to use it is now possible to study the effect of a clear-cut deficiency of riboflavin. When young rats are placed at weaning time upon a diet deficient in riboflavin they do not decline in weight immediately but remain stationary or gain only a very little for the first ten days or two weeks, after which they neither gain nor lose for about three weeks, then decline slowly for a week or so more, and die after having survived complete deprivation for about two months. Riboflavin, whether derived from a food like milk or eggs or given in pure crystalline form, brings a quick response in growth when fed to a deficient animal, if the deficiency is not too far advanced.

The Health of the Skin

After young rats have been on a riboflavin-deficient diet for seven or eight weeks, other signs of nutritional failure besides inability to grow begin to manifest themselves. If there is a trace of riboflavin in the diet they live longer and there is more opportunity for pathological symptoms to develop. Daniel and Munsell of the Bureau of Home Economics of the United States Department of Agriculture found that animals kept on a good diet until six weeks of age and then put on one almost but not absolutely deficient in riboflavin never grew, but maintained their initial weight for over a year. During this

time other deficiency symptoms developed, such as loss of hair (alopecia), which was most marked in the younger animals. It occurred in irregularly distributed patches, beginning generally at the side or on top of the head, the sides or front of the neck, or about the shoulders. In severe cases it led to almost complete denudation of head, trunk, and neck. The early stages of this denudation may be seen in the animal in Fig. 97, whose coat has a distinctly "moth-eaten" appearance. Sometimes the hair will fall out about the eyes, giving the animals a peculiar "spectacled" appearance. These authors also reported finding enormous hairballs in the stomach, which is not strange, considering how easily the fur pulls out.

Other symptoms are a sore mouth, inflammation starting at the corners and sometimes progressing over the whole lower lip; also a bloody, swollen nose, matting of the fur on the hind paws, and certain skin conditions. The dermatitis described by Goldberger in 1926 as a thickening of the skin, cracking and desquamation, leaving a denuded pale pink, glistening skin has since been shown to be due to a deficiency of both riboflavin and pyridoxine. This points out the difficulty in obtaining at that time clear-cut deficiency symptoms.

In 1938, Sebrell and Butler² of the National Institutes of Health, United States Public Health Service, published the first description of proved riboflavin deficiency in human beings, a condition for which they proposed the name ariboflavinosis. Their subjects were 18 women who, on a diet extremely low in riboflavin, developed cracking of the skin at the corners of the mouth and an oily dermatitis around the folds of the nostrils, conditions which could be made to disappear only by giving riboflavin. When riboflavin was discontinued the cheilosis, as the cracking of the skin at the angles of the mouth is called, reappeared, but treatment with riboflavin caused it to disappear again, proving conclusively that the condition was due to riboflavin deficiency, since no other additions that were tried had any effect. A more detailed account of this work was published in 1939.³ Since these reports by Sebrell and Butler several others have appeared confirming and extending their findings, a particularly inter-

² Sebrell, W. H., and Butler, R. E. "Riboflavin Deficiency in Man." *Public Health Reports*, Vol. 53, page 2282 (1938).

³ Sebrell, W. H., and Butler, R. E. "Riboflavin Deficiency in Man." *Public Health Reports*, Vol. 54, page 2121 (1939).

esting one being that of Sydenstricker⁴ and his co-workers who found this condition of cheilosis in a group of hospital employees who had developed it in spite of being free to choose their food from an adequate institutional dietary. A study of their freely chosen food intakes, however, revealed the fact that their consumption of milk, eggs, and green vegetables was so low as to make their diets deficient in riboflavin, thus accounting for the cheilosis and the oily dermatitis as well as eye disturbances which will be referred to in the following section. Still another symptom which has been described as a result of riboflavin deficiency is a specific type of glossitis, an abnormally smooth condition of the tongue caused by a flattening of the tiny protuberances (papillae) of its surface and accompanied by a change of its color to purplish-red.⁵ This condition also responds promptly to the addition of riboflavin to the diet.

The Health of the Eyes

In their classic paper in 1926,⁶ Goldberger and Lillie of the United States Public Health Service remarked: "After a variable period following the arrest of growth already mentioned, there has been observed in many of the animals so fed a tendency for the lids of one or both eyes to adhere together with, in some instances, an accumulation of dried secretion on the margin of the lids." The same phenomenon was observed by various later workers and in other animals as well as in the rat.

In 1931 Day of the University of Arkansas reported that on a diet entirely free from riboflavin all but 2 of a group of 37 rats developed a whitish appearance of the eyeball which upon examination with the ophthalmoscope proved to be due to cataract. The studies with rats were later continued with mice, chicks, and monkeys, and in these species, too, cataract developed upon with-

⁴ Sydenstricker, V. P., Sebrell, W. H., Cleckley, H. M., and Kruse, H. D. "The Ocular Manifestations of Ariboflavinosis." *Journal of the American Medical Association*, Vol. 114, page 2437 (1940).

⁵ Kruse, H. D., Sydenstricker, V. P., Sebrell, W. H., and Cleckley, H. M. "Ocular Manifestations of Ariboflavinosis." *Public Health Reports*, Vol. 55, page 159 (1940).

⁶ Goldberger, J., and Lillie, R. D. "A Note on an Experimental Pellagra-like Condition in the Albino Rat." *U. S. Public Health Reports*, Vol. 41, page 1025 (1926).

holding riboflavin from the diet and was prevented by the administration of pure, synthetic riboflavin.⁷

Usually the cataracts appeared in both eyes of the rats between the sixtieth and eighty-seventh day, but Fig. 96 shows one animal in which a cataract developed first in one eye (B) and was prevented from appearing in the other eye (A) by immediately giving



(Courtesy of Professor Paul L. Day)

A

B

Fig. 96. Two views of the same rat, B taken after cataract developed in the left eye as a result of riboflavin deficiency; A after riboflavin had been administered, the right eye thus being saved.

riboflavin. The eyelids were swollen and almost hairless, but when the vitamin was given new hair began to grow, not only on the eyelids but over the whole body, and a general rejuvenation took place except that the lens opacity did not clear up. There seems to be no mechanism for the repair of such a damage. More recently corneal opacities have been found to be related to amino acid deficiencies. Thus, whether riboflavin is alone involved in cataract formation is yet to be proved. Just what bearing this may have on cataract in man is still unknown.

Sydenstricker, Sebrell, Cleckley, and Kruse⁸ in 1940 published

⁷ Day, P. L. "Vitamin G Deficiency." *American Journal of Public Health*, Vol. 24, page 603 (1934).

⁸ Sydenstricker, V. P., Sebrell, W. H., Cleckley, H. M., and Kruse, H. D. "The Ocular Manifestations of Ariboflavinosis." *Journal of the American Medical Association*, Vol. 114, page 2437 (1940).

two papers concerning the effects of riboflavin deficiency on the eyes of 47 human subjects, among them the hospital employees already referred to. The symptoms found were a dislike of light (photophobia); watering, itching, and burning of the eyes; swelling, soreness, and a feeling of roughness in the eyelids; eyes easily fatigued and dimness or blurring of vision. When the eyes were examined by means of the slit lamp used by ophthalmologists an ingrowing of capillaries into the cornea was found, the extent of the damage depending on how long the deficiency had existed. This condition of superficial vascularizing keratitis, as it is called, responded to the administration of riboflavin but not of thiamine, ascorbic acid, vitamin A, or nicotinic acid. After curing it with riboflavin and then discontinuing the vitamin the condition would develop again, proving it to be a specific effect of riboflavin deficiency.

These investigators considered this keratitis quite analogous to the condition in the rat produced and described by Bessey and Wolbach. They also noted that it occurred in their subjects along with the skin manifestations of riboflavin deficiency described in the previous section—cheilosis, oily (seborrheic) dermatitis, and glossitis—and that all four symptoms responded to administration and withdrawal of riboflavin, although the eye symptoms regularly appeared first. They believe that ariboflavinosis may possibly be the most prevalent simple avitaminosis and that these changes in the eye, which occur very promptly when riboflavin is withdrawn, make this avitaminosis more easily recognizable than others. They call attention to the fact that eye symptoms often ascribed to toxic conditions or focal infection or eye strain may well be due to too low intake of riboflavin and be found to respond to administration of the vitamin.

Spies and his associates have found cheilosis and keratitis so prevalent among infants and children in a region in the South where deficiency diseases are endemic and have obtained such prompt response to administration of riboflavin alone that they feel convinced that ariboflavinosis is the most common clinical deficiency disease occurring among infants and children in such a region.

Riboflavin and Reproduction

The fact that riboflavin is known to be essential for the development of new tissue directs attention to its importance in reproduction. Warkany in 1940 reported that female rats maintained on a

diet deficient in riboflavin produced young showing congenital skeletal malformations which included shortening of the mandible, tibia, fibula, radius and ulna; fusion of the ribs, sternal centers of ossification, fingers, and toes; and cleft palate. These conditions developed in 30 per cent of the young of the riboflavin-deficient rat mothers. Further studies by Warkany and his associates show that whether riboflavin is present in adequate amounts or absent between the thirteenth and the fifteenth days of gestation makes a difference in the development of the skeleton of the fetus. This work has been carried out on experimental animals, but its application to human nutrition has not as yet been established.

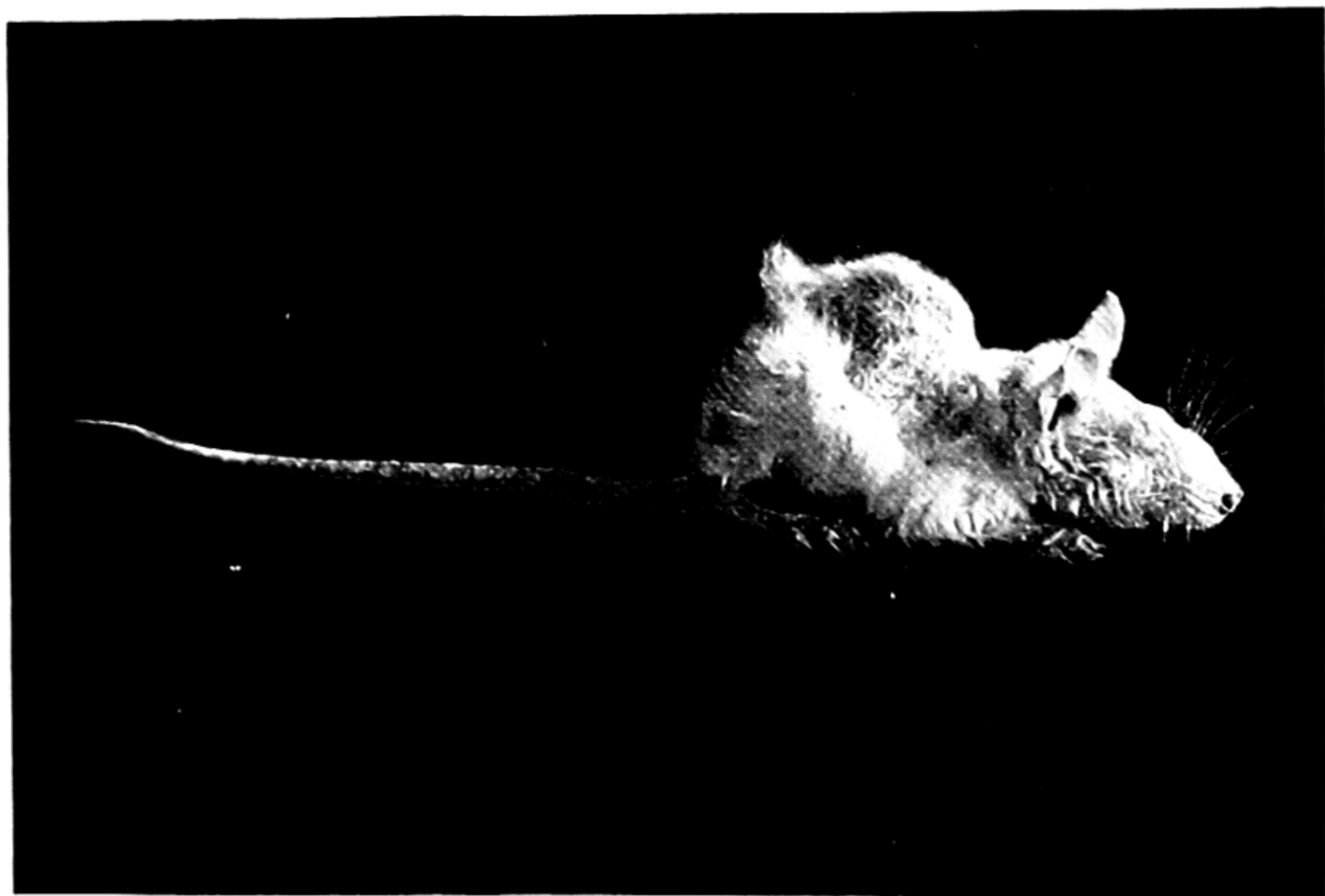
Other studies on the reproductive cycle of the rat show that although little riboflavin seems to be required during the early period of pregnancy there is a major increase during the later period when the demand for riboflavin in the formation of new tissue is greater. Similar results have been obtained in preliminary studies of human pregnancy.

Braun and his associates in 1945 reported finding evidence of a riboflavin deficiency in about one-fifth of a group of 900 Jewish women in the low economic group in Palestine. The typical symptoms of ariboflavinosis such as cheilosis, corneal vascularization, angular stomatitis, glossitis, and heartburn appeared in many of these women in about the third trimester of pregnancy. The average intake of these women was found to be below 1.3 milligrams per day. This is considerably below the 2.0 milligrams of riboflavin recommended for the third trimester of pregnancy by the Food and Nutrition Board. The symptoms improved when they were given either yeast extract or riboflavin.

Maintenance of Health and Vigor at All Ages

Extensive investigations of the effects of riboflavin on general health and vigor were conducted by Sherman and Ellis, who found that when parallel groups of rats were fed on graded levels of riboflavin intake, beginning with one which supported normal growth and apparently good health, successively more liberal levels resulted in more rapid growth, earlier maturity, better vigor as shown by ability to bear young, postponement of the signs of senility, and "enhancement of nutritional well-being," or as McCollum has aptly said, "preservation of the characteristics of youth." Animals fed more

riboflavin than is required for normal growth to adult size not only lived longer but had a longer period of adult vigor and a relatively short period of senility. In Fig. 97 is shown a rat that had just enough



(Courtesy of Professors H. C. Sherman and M. R. Sandels)

Fig. 97. This rat is eight months of age and weighs less than at the age of four weeks. A normal animal of this age will weigh from 200 to 300 grams. The failure to grow and the senile appearance are due to lack of riboflavin.

riboflavin to ward off death. It became weak and depressed, but living a sheltered life, protected from strain and other vicissitudes, it was able to continue a miserable existence for many months.

Withholding of riboflavin causes no abrupt and complete loss of appetite, as does deprivation of thiamine, but the impulse to eat is depressed somewhat, so that about two-thirds as much food per gram of rat is consumed as would be eaten by a normal animal. This means, of course, a lowering of the supplies to the body of all essentials and unless the diet is extraordinarily well fortified, there are likely to be secondary effects due to deficiencies of other essentials. This appears particularly to be the case with thiamine and niacin, so that riboflavin shortage is often complicated by a further failure of appetite and symptoms of polyneuritis.

Digestion is usually impaired, with general weakness and loss of

good muscle tone. Sherman has summarized the general situation thus: "Riboflavin is essential to growth and to normal nutrition at all ages. When the food is distinctly poor in riboflavin for any considerable length of time, digestive disturbances, nervous depression (different from the symmetrical polyneuritis of thiamine deficiency though both may occur in the same person), general weakness and deterioration of tone, and poor condition of the eyes and skin are apt to develop; the incidence of infectious disease is likely to be increased, vitality diminished, life shortened, and the prime of life curtailed by the unduly early development of the physical manifestations of old age." ⁹

Measurement

The methods most commonly used for the quantitative determination of riboflavin are modifications of the fluorometric and microbiological methods. These methods have replaced the biological assays which are more laborious.

The biological methods were usually conducted on rats although chicks were also used. The rat was generally considered the more dependable animal for quantitative determination of the vitamin. The Sherman-Bourquin growth method was the most widely used in early studies.

The microbiological method involves the use of riboflavin as a growth factor for certain lactic acid bacteria. In 1939 Snell and Strong suggested the use of a strain of *Lactobacillus casei* for the measurement of riboflavin, and the procedure developed and modified by them has been found satisfactory and useful.

The fluorometric methods consist in measuring quantitatively the fluorescence of riboflavin by means of the fluorometer. Microfluorometric methods have also been developed.

The riboflavin content of foods is expressed in terms of micrograms or milligrams per 100 grams of food.

Sources

In most of the foods which contain it, riboflavin is associated with thiamine and with other vitamins in the so-called vitamin B com-

⁹ Sherman, H. C. *Chemistry of Food and Nutrition*, 8th edition, page 395. The Macmillan Co. (1952).

Riboflavin

plex. The only food in which riboflavin is known to occur without thiamine is white of egg. The richest known source is dried brewer's yeast, but liver is also a rich source, and kidney only a little less so. Muscle meat, whether beef, lamb, or veal, is less than one-tenth as rich as liver. The egg yolk, weight for weight, is about twice as rich as the egg white. Milk is doubtless the most important source of riboflavin. Weight for weight, Cheddar cheese is about equal to egg yolk.

Among vegetable foods, green leaves are the best sources but peas and beans (either fresh, dried, or frozen) are also good sources. The cereal grains are in general poor sources. In fact, the poverty of whole wheat and whole corn in this vitamin was one of the factors which led to its identification as a separate vitamin. The cereals rank with the potato as among the poorest of vegetable foods which have been investigated. Most of the vitamin is in the germ, and when this is separated from the rest of the grain it becomes an excellent source.

Heating does not readily destroy this vitamin; consequently, canned foods are about as rich in it as the original food before preservation. Meat will lose 15 to 30 per cent of its riboflavin during the processes of braising, roasting, or boiling. Williams and Cheldelin found that when they heated a solution of pure riboflavin exposed to light, considerable destruction of the vitamin occurred whereas in an identical solution heated in the dark there was no destruction. These findings indicate that in cooking riboflavin-containing foods conservation of the vitamin will be promoted by excluding light as much as possible. Three-fourths of the riboflavin in milk may be destroyed if it remains in direct sunlight for three and one-half hours. Riboflavin values for foods are given in Tables II and IV in the Appendix. See Fig. 98 for a comparison of foods having the same amounts of riboflavin.

Requirement

From studies of excretion of riboflavin at various levels of intake to determine the amount required by man it has been found that intakes of 1.1 to 1.6 milligrams daily will provide adequately for body storage. Sebrell and his associates studied a group of women on an intake of 0.5 milligram of riboflavin per day. They developed signs of a riboflavin deficiency within three to eight months. Horwitt

and associates studying a group of men on an intake of 0.55 milligram of riboflavin noted deficiency lesions within four to ten months. Apparently, skin lesions, such as angular stomatitis, will appear when the intake of riboflavin is less than 0.75 milligram per day. Other studies have shown that riboflavin-deficiency lesions have not been noted on levels above 0.75 milligram per day and some of these studies were continued for as long as two years.

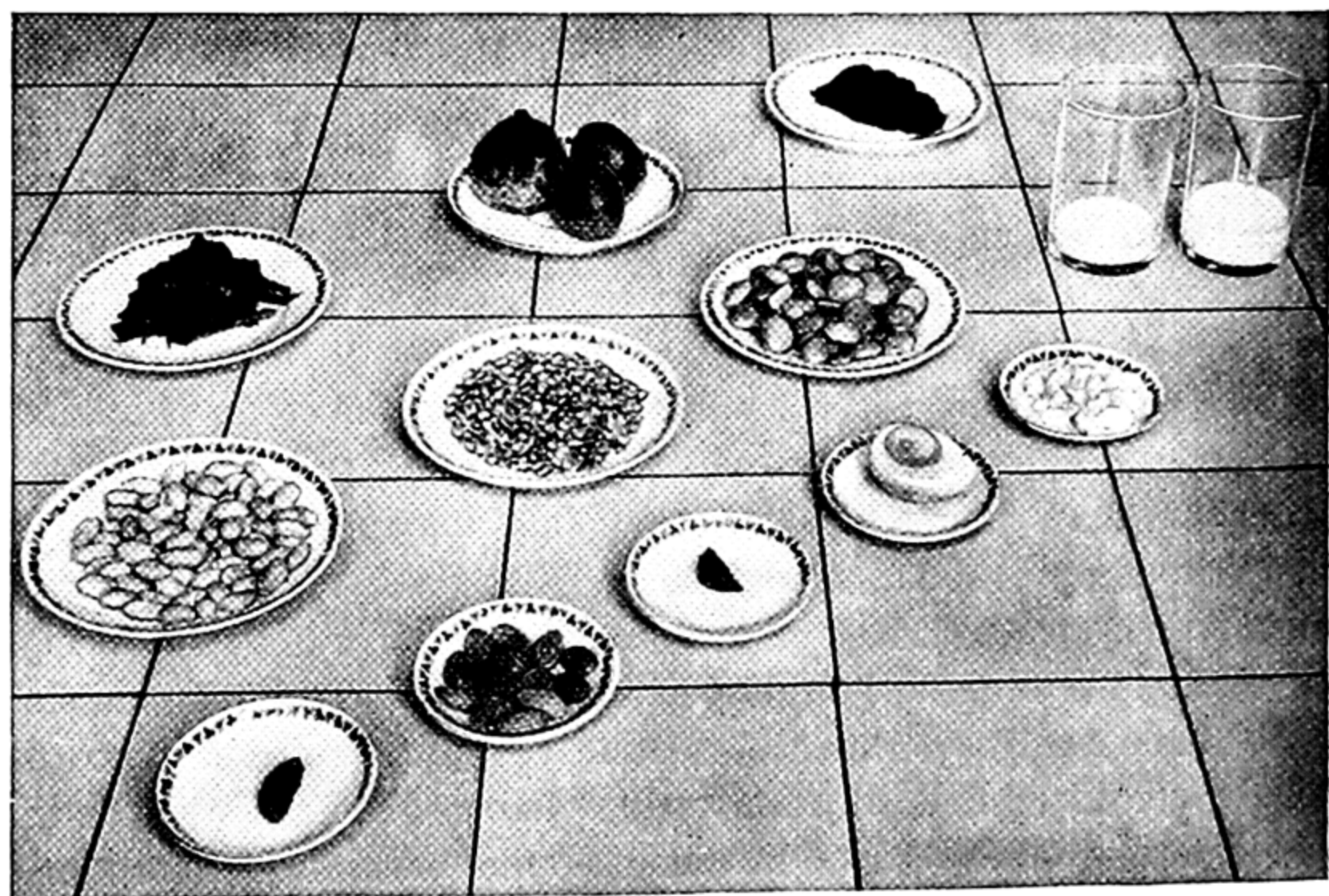


Fig. 98. Food Portions Yielding 0.10 Milligram (Two Shares) of Riboflavin

	<i>Grams</i>		<i>Grams</i>
Spinach, cooked	50	Milk, whole	56
Beets	200	Kidney, A.P.	4
Beef, round, lean	50	Almonds, shelled	15
Peanuts, shelled	63	Liver, beef, fried	3
Peas, dried	36	Egg	27
Beans, Lima, steamed	114	Cheese, cottage	32
Milk, evaporated	28		

Attempts were then made to evaluate the supply of riboflavin in the tissues by comparing the intake of riboflavin with the amount excreted in the urine. Horwitt and associates studied the amount of riboflavin excreted at different levels of intake and found that to maintain a tissue reserve it was necessary to have an intake of at least 1.1 milligrams per day. Studies made by Davis and associates

on women showed that tissue requirements could be met by intakes of 1.0 milligram of riboflavin per day.

On the basis of these studies and others, the Food and Nutrition Board of the National Research Council has recommended 1.6 milligrams of riboflavin daily for the "reference man" and 1.4 milligrams daily for the "reference woman." These amounts are aimed at optimal rather than merely adequate levels. It is reasonable to believe that the improvements seen in animals when the level of riboflavin intake is increased might well be shown by human beings who apply these results to their own dietary habits.

For recommendations for pregnancy, lactation, infants, and children of different ages, see Tables I(a)(b)(c)(d) and III(a)(b)(c)(d) in the Appendix.

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Niacin (Nicotinic Acid)

Pellagra

In 1914 pellagra, a disease which had been more or less prevalent in certain sections of Europe for 200 years, began to develop alarmingly fast in some of our southern states. Goldberger decided to find out its cause. This decision was timely, for in 1915 over ten thousand persons died of the disease in the United States, and by 1917-18 two hundred thousand were suffering from it.

Pellagra is a peculiar disease, seasonal in its outbreaks, 90 per cent of the cases having their onset in the period from April to July, with remissions in the late fall and winter. Its symptoms are many and varied, but among the most typical is a skin eruption which at first resembles sunburn, but later becomes dark and makes the skin rough and scaly. It attacks only certain parts of the body surface, particularly the backs of the hands in adults and of the feet in children. Other parts not infrequently attacked are the sides or front of the neck, the face, elbows, and knees. Another marked peculiarity is its tendency to appear at about the same time on both sides of the body. If the back of one hand or one cheek is affected, the corresponding part on the opposite side is involved also. Accompanying the skin eruption are soreness of the mouth and redness of the tongue, indigestion and diarrhea, and disturbance of the nervous system leading in the severest cases to insanity. The mortality records tell the smallest part of the misery it entails, due to lowered physical and mental standards and reduced capacity for the enjoyment of life. The poor man was always the chief victim, but the limitation of the disease to certain rather clearly defined geographical areas indicated that other factors besides poverty were involved. In

Great Britain the endemic disease of the poor has been rickets; in the Far East it is beriberi; in the cotton mill villages of the South and in southern rural districts of the United States where cotton is practically the only crop, it has been pellagra.

The first scientific description of the disease was written by a Spaniard named Casal in 1735. He noted the very poor diets in the pellagrous districts of Andalusia and attributed the disease to faulty nutrition. A few years later it was recognized and named in Italy, pellagra being an Italian word meaning rough skin. Subsequently it spread into France, Hungary, Rumania, Turkey, and Greece. In 1845 a French physician, Dr. Roussel, wrote a treatise on pellagra in which he, too, pointed out that it is a nutritional disease and recommended broth, meat, milk, eggs, and fish as the best cure. At the close of World War I pellagra broke out in Egypt in camps for Armenian refugees and for prisoners of war. Dr. Wilson of Cairo, who studied the diets, thought them too low in protein and cured the victims by the addition of meat and milk to their high cereal diets.

Experimental Pellagra

In the parts of the South where pellagra was becoming a scourge in 1914, the main agricultural crop was cotton and the people subsisted on foods bought in the local groceries, mainly cornmeal and grits, white flour, polished rice, sugar, molasses, and fat pork. In mill villages there were no butcher shops nor dairies and even in the rural districts few persons kept any cows, poultry, or other live stock. A survey made by Goldberger convinced him that "the suspicion of pellagra may with confidence be dismissed in one who is a habitual milk drinker and meat eater," but he determined to put the matter to the test, just as Eijkman had done in the case of beriberi in Java, and see whether pellagra could be induced in healthy men by dietary measures.

He selected for his experiment the farm of the Mississippi State Penitentiary where there was a camp well isolated from the surrounding communities (to rule out the possibility of bacterial infection) caring for some 70 to 80 convicts. On promise of a pardon from the governor of the state, 12 men volunteered to serve as subjects (later one was dismissed) and at the beginning of February 1915, they were quartered in a small screened cottage and kept under guard day and night. Until April 19 they had the usual prison fare

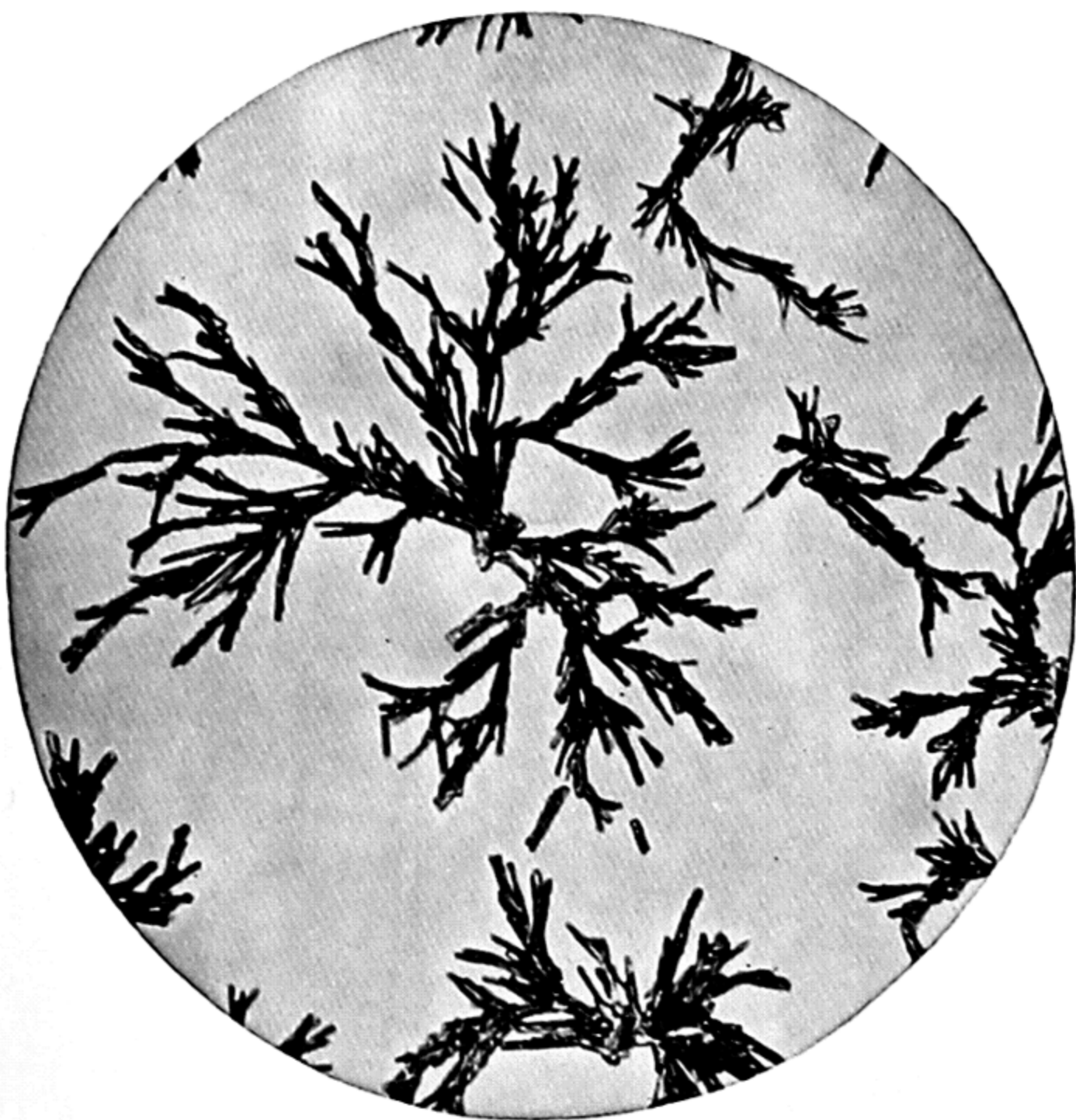
and there were no signs of pellagra. They were then put on an experimental ration consisting chiefly of cornmeal and grits, cornstarch, white flour, rice, cane syrup and sugar, sweet potatoes, and pork fat, with exceedingly small amounts of turnip greens, cabbage, and collards. The average protein intake was only 6 per cent of the total calories and from 80 to 97 per cent of the total protein came from the cereal foods. Six men developed symptoms which were deemed sufficient to justify a diagnosis of pellagra by November 1. No one in the camp not on the volunteer squad showed any sign of the disease. In concluding the investigation Goldberger said: "In relation to the study of pellagra this study suggests that the dietary factors to be considered as possibly essential are (1) an amino acid deficiency, (2) a deficient or faulty constitution of the mineral supply, possibly, but doubtfully, (3) a deficiency of the fat soluble vitamine intake, and perhaps (4) an as yet unknown (vitamine?) factor. As to which or what combination (or combinations) of these constitutes the specific pellagra-producing dietary defect or defects remains to be determined."¹

Studies on human subjects in certain asylums in which pellagra recurred regularly showed that addition to the diet of purified protein only was without effect, but that dried brewer's yeast was able to give good protection in doses of about 2 ounces daily, and that an extract of yeast free from protein was equally effective. These results ruled out an amino acid deficiency as the cause of pellagra. Continuing their investigations, Goldberger and his associates in 1926 established the fact that yeast which, because of heating, had lost its antineuritic property, still contained a substance active in curing pellagra. They named this then unknown substance the P-P (pellagra-preventive) factor. When riboflavin (present in the heated yeast) became available in pure form, experiments on dogs were immediately carried out to determine whether it was the P-P factor. By this time there was general agreement that the condition in dogs known as blacktongue was closely analogous to that of pellagra in the human being. Blacktongue can be produced in dogs by the typical diet of pellagrins, in fact, the dogs of pellagrous families are frequently found to be suffering from blacktongue, doubtless due

¹ Goldberger, J., and Wheeler, G. A. *The Experimental Production of Pellagra in Human Subjects by Means of Diet*. Hygienic Laboratory, United States Public Health Service, Bulletin No. 120 (1920).

to being fed the table scraps of the family. Riboflavin was found to be entirely ineffective in experimental blacktongue in dogs² and administration of the pure substance to a number of pellagra patients proved that it alone was not capable of inducing a cure.

The final solution of the possibilities suggested by Goldberger and Wheeler in 1920 came in the late summer of 1937 when Elvehjem and his associates at the University of Wisconsin announced that they had succeeded in both preventing and curing blacktongue in dogs by



(Courtesy of Parke, Davis and Co.)

Fig. 99. Crystals of Nicotinic Acid (Niacin)

administration of either nicotinic acid or its amide. These substances were promptly tried in cases of human pellagra and found to give truly spectacular results, beneficial effects being seen within 24 to

² Sebrell, W. H., Hunt, J. D., and Onstott, R. N. "Lactoflavin in the Treatment of Canine Blacktongue." *United States Public Health Reports*, Vol. 52, page 235 (1937).



*(Courtesy of Professors J. M. Ruffin and D. T. Smith,
Duke University School of Medicine, Durham, N. C.)*

Fig. 100. Appearance of the hands of a pellagra patient on admission to a hospital (upper) and after three weeks of treatment with niacin (lower).

Niacin (Nicotinic Acid)

48 hours even when the disease had progressed to the stage of producing mental derangement. Thus the identity of the P-P factor was finally established. Because the name nicotinic acid associates this compound with the nicotine of tobacco and this is considered undesirable for a food constituent, another name for the compound was sought. Of those proposed the name *niacin* (*ni* for nicotinic, *ac* for acid, *in* for vitamin), coined by Cowgill of Yale University, was chosen and has been adopted by the United States Food and Drug Administration, but the term nicotinic acid is still used in the scientific literature. The amide of the acid, nicotinamide, is also used in the treatment of pellagra. The name niacin is commonly used to cover the group.

The dog was used as the experimental animal in all the early work in the study of pellagra, but as highly purified rations have been developed which can be supplemented with the B complex vitamins it has been found that the growing chick also needs niacin for optimum growth and for prevention of chick blacktongue. The rat has been found to need niacin in its diet when the tryptophan content of the diet is low or when intestinal bacteria fail to synthesize it.

Functions of Niacin

Niacin functions in metabolism chiefly as a component of two coenzymes, called coenzyme I (or cozymase) and coenzyme II, which are essential for normal oxidation of carbohydrate in the body. It has been found that these catalysts are markedly reduced in amount in the tissues of dogs suffering from blacktongue.

Studies of the end products of niacin metabolism in the urine of human subjects have shown that the amino acid tryptophan is converted to niacin in the body. This conversion has been found also in several species of animals and in microorganisms. Rats ordinarily get all the niacin they need from that synthesized by intestinal bacteria, but on diets containing large amounts of corn they fail to grow normally and show other signs of niacin lack. If either niacin or tryptophan is given in small amount with these diets, symptoms of niacin deficiency do not appear. Corn contains very little niacin, and its chief protein, zein, is a very poor source of tryptophan. The diets high in corn are therefore low both in niacin and its precursor, tryptophan.

Spies has reported occurrence of latent or mild pellagra in infants and children who did not show the usual symptoms of pellagra but

were weak and failed to grow. Treatment with niacinamide brought about improvement in these children. Niacin has also been shown to have a favorable effect in cases of poor appetite and of digestive disturbances.

It has been reported by physicians that while niacin cures pellagra they find that many of their pellagra patients need in addition thiamine or riboflavin or both. Spies found a number of cases who were given the three vitamins and still were not entirely well. He then administered the vitamin pyridoxine and saw improvement. Also it has been found that the anemia in blacktongue of dogs is apparently complicated by a simultaneous deficiency of folacin. Results such as these have led to the suggestion that perhaps we should think of pellagra as a multiple-deficiency disease rather than being due to a specific deficiency of niacin. It is easy to believe that the pellagrin suffers from several deficiencies when one considers the fact that the typical diet of these patients consists very largely of corn bread, syrup, and fat pork.

Measurement

The dog is the only animal that has been used satisfactorily in assaying foods for niacin content. The bioassay method is used to measure the growth response of puppies or the cure of blacktongue in adult dogs. However, both of these techniques present many problems, for example, to obtain a satisfactory growth response the substance to be tested must be freed of protein and amino acids, especially tryptophan; and it has been found that the curative effect of niacin in foods does not always run parallel with the prevention of blacktongue in dogs. Chemical methods are not widely used because of difficulty in obtaining complete liberation of niacin without the formation of interfering substances. The most satisfactory methods are the microbiological, of which that of Snell and Wright is the most commonly used.

Sources

Niacin values of foods will be found in Table 44 in *Rose's Laboratory Handbook for Dietetics* by Taylor and MacLeod. They are also given in *Agriculture Handbook No. 8* by Watt and Merrill of the United States Department of Agriculture. The best sources of niacin

Niacin (Nicotinic Acid)

are liver, lean meat, poultry, yeast, fish, peanuts, beef heart, and whole wheat. Cereals and dried legumes contribute significant amounts. Fruits and vegetables are poor sources as are also cheese, eggs, and milk. The low niacin content of such foods as eggs and milk does not indicate their niacin value in the diet since these foods are known to have excellent pellagra-preventive value due, as we now know, to their proteins having a high tryptophan content.

Since nicotinic acid is a very stable compound, ordinary cooking processes cause very little destruction of it, and therefore losses in cooking are practically negligible if the cooking water is used.

Niacin, thiamine, riboflavin, and iron are now being added to our highly milled cereals, thus compensating for the removal of these nutrients in the milling process. Those who will not use whole wheat flour and bread because they prefer the white are thus protected to a certain extent against deficiency of these four essential nutrients. Special attention should be called to the importance of the enriched degerminated corn and corn grits now generally used in our southern states, where in the past pellagra was so prevalent.

Requirement

An exact figure for human requirement of niacin is difficult to establish since, as learned from the preceding discussion, it is dependent not only on the amount of niacin fed as such but also on the amount of tryptophan present in the food and on synthesis by the intestinal bacteria. This makes it difficult to determine the requirement by balance experiments. That there may be other complications is indicated by such findings as those of Benesch, who found that certain microorganisms may destroy niacin produced by other organisms. Lyman and Elvehjem, studying rats on low tryptophan diets, found that on dextrin diets the requirement was lower than on those in which sucrose was used, indicating an influence of the kinds of food on the amount of niacin required. Sarett reported in 1952 the results of a study which indicated that the intestinal flora in man may furnish only small amounts of niacin above the niacin contained in the diet.

Booher and Behan in 1949 reported analyses of composite food samples representative of the average American dietary which indicated that a diet furnishing 3,050 calories provided 20.2 milligrams

of nicotinic acid, an amount exceeding considerably the recommended allowance of 15 milligrams. It is interesting to compare this figure with those of 4.25 to 10.45 found by Frazier and Friedmann when they calculated from Goldberger's diet records the amounts of nicotinic acid in the diets of families in which pellagra was prevalent. These results plus the rare occurrence of pellagra in America today indicate that the average American diet is adequate in pellagra-preventive factors.

Goldsmith and her associates have reported ^{3,4} investigations carried out on human beings to determine the requirement for niacin. Two different diets were used, one high in corn and the other high in wheat, each furnishing approximately 200 milligrams of tryptophan, little more than the minimum human requirement for this amino acid, and 5 milligrams of niacin. Each of three subjects on the corn diet showed characteristic signs of niacin deficiency after about 50 days on the diet. Of three subjects on the wheat diet one showed typical niacin deficiency at the end of 80 days, a second developed amenorrhea, herpes of the lip, and slight redness of the tongue papillae, while the third showed lassitude and depression as the only clinical effects. The time it took for pellagra to develop and the severity of it seemed to be related to the intake of niacin and tryptophan per unit of body size on both diets but these investigators think this relationship may not be the complete explanation of the differences between the clinical and laboratory findings on the two diets. They feel that the low tryptophan content of corn may not be the sole explanation of the pellagra-producing properties of corn. They conclude from their findings on supplementing the corn diet with niacinamide that body stores of the vitamin approach adequacy when the diet furnishes 8 to 10 milligrams of niacin.

The recommended dietary allowance suggested by the Food and Nutrition Board in 1948 was that it should be ten times the thiamine allowance. Since tryptophan acts as a precursor of niacin and we have, as yet, little accurate knowledge of the amino acid content of diets, the Board recommends that the 1948 allowance be retained.

³ Goldsmith, G. A., Sarett, H. P., Register, U. D., and Gibbens, J. "Studies of Niacin Requirement of Man. I. Experimental Pellagra in Subjects on Corn Diets Low in Niacin and Tryptophan." *Journal of Clinical Investigation*, Vol. 31, page 533 (1952).

⁴ Goldsmith, G. A., Rosenthal, H. L., Gibbens, J., and Unglaub, W. G. "Studies of Niacin Requirement in Man. II. Requirement on Wheat and Corn Diets Low in Tryptophan." *The Journal of Nutrition*, Vol. 56, page 371 (1955).

Niacin (Nicotinic Acid)

This will be found in Table III(a) in the Appendix. It would seem to be true that if one lives on a well-mixed diet which meets the recommended allowances for all the other nutrients there is probably little chance of a deficiency of niacin.

Prevention of Pellagra

Those who have worked most intensively on the relation of nicotinic acid to human pellagra have repeatedly called attention to the importance of educating the pellagrin, while treating with such specifics as niacin, thiamine, riboflavin, etc., to the consumption of an adequate diet so that when he is dismissed from the hospital he will not go back to the poor diet which was the cause of his illness. This is an educational process of first importance in regions where pellagra is endemic.

A number of field studies made before the discovery of the part played by nicotinic acid had proved that pellagra could be controlled through diet. In 1932 Stiebeling and Munsell of the Bureau of Home Economics, United States Department of Agriculture, investigated the food supply of 73 South Carolina farm families and its relation to the incidence of pellagra, dividing them into two groups: (a) 44 families in an unsatisfactory economic situation, members of which were suffering from pellagra or in imminent danger of doing so soon; and (b) 29 families whose economic condition indicated that they could without aid maintain themselves in a better state of nutrition than the other group. To each of the families in the first group some kind of pellagra-preventing food was furnished, dried or evaporated milk, wheat germ, cured lean pork, canned tomatoes, or pure dry yeast being chosen for the purpose. Periodic examination of these 44 families for pellagra revealed that the incidence and severity of the disease were less than in former years and much less than in unaided families of similar resources during the period under observation. The families successful in warding off pellagra used diets more abundant in every respect, furnishing on the average $2\frac{1}{4}$ cups of milk per person per day, about 3 ounces of fruit and succulent vegetables, and about 3 ounces of lean meat. The families in which over a parallel period pellagra occurred used on the average less than $\frac{1}{5}$ of a cup of milk, less than 3 ounces of vegetables and fruits, and less than 3 ounces of lean meat, fish, and eggs together, per person per day.

One is reminded of Goldberger's statement regarding possible benefit to pellagrins from a change to the country: "Practically, so

far as pellagra is concerned, all the benefits of a 'change of climate' may be had at home at the cost of half a gallon of milk or half a pound of stew beef a day." ⁵

In the same year another field study was reported by Sandels and Grady of the Florida State College for Women. Careful comparisons of the diet of 16 pellagrous and 13 nonpellagrous families were made at four seasons of the year. Recurrence of pellagra occurred most frequently in March and April, before the increased food supply of the spring was available. The most important difference in the dietaries was in the amount of milk, the mean per cent of the total calories from this food being in each of the four periods from two to three times as high in the nonpellagrous as in the pellagrous families. Differences in the succulent vegetables were also outstanding, especially in the winter, when the nonpellagrous families averaged 8.8 ounces per man per day while the pellagrous families had only 2 ounces per man per day.

Wheeler and Sebrell of the United States Public Health Service, also in 1932, stated as their conclusion from their studies that under institutional conditions, where the diet can be controlled, the problem of pellagra can be eliminated. They said, "By a few simple and comparatively inexpensive additions to the daily menu, one state institution for the insane, the largest in the South and second largest in the country, has reduced the annual death rate from pellagra from 6.2 per cent of all inmates to as low as 0.1 per cent, this in spite of the fact that during the same time deaths from this cause for the state at large increased almost 100 per cent. . . . Except under extremely reduced resources, its conspicuous presence in any community in which the diet is subject to regulation by central authority can no longer be justified." And further, regarding the pellagrous districts in the country at large they made this significant statement: "In looking for cases of pellagra, the home surrounded by evidence of a good garden, or a cow or two, a few pigs and some poultry may as well be passed up, for the chances are less than one in a thousand that pellagra will be found. On the other hand, the home surrounded only by last year's cotton patch will always bear watching." ⁶

⁵ Goldberger, J. "Pellagra: Its Nature and Prevention." *United States Public Health Reports*, Reprint No. 461, pages 481-488 (1918).

⁶ Wheeler, G. A., and Sebrell, W. H. "The Control of Pellagra." *Journal of the American Medical Association*, Vol. 99, page 95 (1932).

This statement, made in 1932, is very interestingly supported by the results of a survey, reported in 1941, of two adjacent localities in the Kentucky mountains, one of which, a rural community, was found to be free of pellagra, while in the other, a coal mining community, pellagra was endemic. Kooser and Blankenhorn,⁷ looking for an explanation of this striking difference between two groups of similar economic level, found that the rural group, in which pellagra had formerly been endemic, had been so influenced by the teaching of the Frontier Nursing Service nurses concerning the relation of food to health that they had planted gardens and were keeping cows and chickens, while in the mining district, where no such service had been available, only insignificant gardens were found. The greatest differences in food consumed by the two groups were found to be in the amounts of milk and eggs, the families in the rural area using much more of each because of producing them for themselves. This serves as an excellent practical demonstration of the pellagra-preventive value of milk and eggs, notwithstanding the low nicotinic acid values which have been reported for these foods.

It is fortunate that such studies as those cited enable us to list the kinds and amounts of foods which have been found to prevent pellagra in human beings. The results of these investigations enable us to say with assurance that any one item in the following list will furnish full pellagra prevention for one day:

One quart of milk or buttermilk
One pint of evaporated milk
One-third to one-half pound of
dried skim milk or
lean meat, or
canned salmon, or
peanut meal, or
wheat germ

One pound of
fresh or
canned collards, or
kale, or
green peas, or
turnip greens
Two to three pounds of
fresh tomatoes, or
canned tomatoes, or
tomato juice

Any combination of fractional parts of these individual items can, of course, be made; for example 1 pint of milk (half the amount

⁷ Kooser, J. H., and Blankenhorn, M. A. "Pellagra and the Public Health: A Dietary Survey of Kentucky Mountain Folk in Pellagrous and Non-Pellagrous Communities." *Journal of the American Medical Association*, Vol. 116, page 912 (1941).

listed) and 3 or 4 ounces of lean meat consumed in one day will give the desired protection.

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Other Vitamins

Just as investigations of the functions of the glands of internal secretion have revealed a multiplicity of hormones undreamed of not many years ago, so the researchers on the sources and functions of the vitamins are bringing to light a larger number of these controlling factors in the infinitely complex organization of the living body. In this chapter a number of these will be discussed briefly, although the significance of many of them in the human organism is still unknown.

Vitamin E (Tocopherols)

DISCOVERY. The first positive indication that a diet which would enable an animal to grow to maturity in apparently excellent health might still be inadequate for reproduction was furnished in 1920 by Mattill of the State University of Iowa, who was seeking an answer to the question: Is milk, which so admirably meets the needs for growth of the young, a food which will furnish all dietary requirements through the whole life span? Young rats were found to prosper till they approached maturity (at the age of about two months), when they grew somewhat more slowly and failed to reproduce. Various additions to the diet, such as iron, yeast, and butter, were tried without success and the investigators were at a loss for an explanation. This was furnished in 1922 by Evans of the University of California. As an anatomist interested in the physiology of reproduction he had begun in 1921 to study the influence of diet upon the estrus cycle of the rat and very soon discovered that failure of ovulation occurred regularly on diets insufficient in vitamin A, even though they furnished enough for fair growth. Further investigation

with a highly purified ration, thought to be adequate in everything but vitamin A, revealed that it could not be made satisfactory for reproduction even when much vitamin A in the form of cod liver oil was added.

The animals raised on this diet had every appearance of health, being "of splendid size, sleek-coated and active" but they bore no young. They would exhibit normal estrus cycles, breed, ovulate, and conceive, but something would happen to the placenta which resulted in the death of the fetus. No improvement resulted when the character of the protein of the diet was changed or increases made in the amounts of vitamins A, thiamine, and D. But fresh lettuce was very effective. The possible influence of ascorbic acid was ruled out



(Courtesy of Distillation Products, Inc., Rochester, N. Y.)

Fig. 101. Crystals of Vitamin E Palmitate

because whole wheat or a powder of dried lettuce leaves heated to destroy ascorbic acid was curative, too. Careful work with wheat embryo revealed a remarkable potency, only $\frac{1}{4}$ gram daily being

needed to restore normal fertility. Evans concluded that there was a special fertility factor and it soon came to be known as vitamin E.

After much careful research Evans and his associates, in 1935, obtained from wheat germ oil a crystalline compound belonging to the alcohols of high molecular weight (sterols), which was potent for the prevention of sterility. To this they gave the name alpha-tocopherol.¹ Since the identification of alpha-tocopherol three other naturally occurring substances have been found which have the same function. These have been named beta-tocopherol, gamma-tocopherol, and delta-tocopherol. These compounds are so much alike in activity that the term vitamin E is used for them collectively. Many synthetic compounds chemically related to these tocopherols are now known which exhibit vitamin E activity.

PREVENTION AND CURE OF STERILITY. Lack of vitamin E does not prevent the development of a normal individual, but, in the rat at least, it does result in sterility. In the male there is destruction of the germ cells; in the female the estrus cycle is normal and there is no failure of ovulation, the developing ova are fertilized and implanted and the embryos begin to grow rapidly, but often by the eighth day, when more than a third of the gestation period has been completed, retardation in development can be observed, and at some time between the twelfth and twentieth day fetal death occurs, followed by resorption of the fetus. In no other type of dietary deficiency is this peculiar failure of placental function known to occur regularly.

That vitamin E is transferred from mother to offspring during intrauterine life is proven by the fact that the tissues of newborn rats cure female dietary sterility. If rats of proven fertility are placed on a diet lacking vitamin E, they will remain fertile for three or four months, thus showing that vitamin E can be stored in the body. Further evidence on this point has been obtained by feeding to a certain number of sterile females various tissues (liver, muscles, fat) derived from other sterile females, and to another group of sterile animals tissues from animals of proven fertility. In all instances the tissues of rats whose diet contained vitamin E provoked fertility, but in no case did the tissues of sterile rats cure sterility in another animal.

Whether vitamin E plays a role in human reproduction is not

¹ Evans, H. M., Emerson, O. H., and Emerson, G. A. "The Isolation from Wheat Germ Oil of an Alcohol, α -Tocopherol, Having the Properties of Vitamin E." *Journal of Biological Chemistry*, Vol. 113, page 319 (1936).

proven. There have been some reports of treatment with the vitamin being beneficial in cases of sterility in man and of abortion in pregnant women, but these have been offset by reports of negative results. Since vitamin E is widely distributed in common foods it is not thought likely that cases of sterility or habitual abortion indicate a vitamin E-deficient diet but rather some abnormality in the absorption or metabolism of the vitamin. At all events the amounts needed under normal conditions are certainly small and its very wide distribution in food materials insures a considerable intake. It occurs in the greatest richness in the oils of wheat germ, corn, cottonseed, and soybean, but is found in abundance in legumes, green leaves, whole grains, eggs, liver, butter, margarine, and most vegetables. The average daily intake for the adult man has been estimated to be about 14 to 19 milligrams.

OTHER FUNCTIONS OF VITAMIN E. It has been found in animals other than the rat that vitamin E deficiency manifests itself differently. In several species of animals (guinea pigs, rabbits, sheep, goats, hamsters, and others) lack of vitamin E in the diet results in severe degeneration of the skeletal muscles without, apparently, any effects on other organs or tissues of the body. This nutritional muscular dystrophy in these animals is now recognized as a specific effect of vitamin E deficiency. In extensive studies of progressive muscular dystrophy in human beings it has been found that neither alpha-tocopherol nor wheat germ oil has any beneficial effect.

In some species it has been found that lack of this vitamin retards growth, while in others this effect is not seen. In other species (young chicks, for example) the result of the deficiency is a condition known as nutritional encephalomalacia, in which there is severe injury to the brain causing paralysis. Adverse effects on heart action have also been reported.

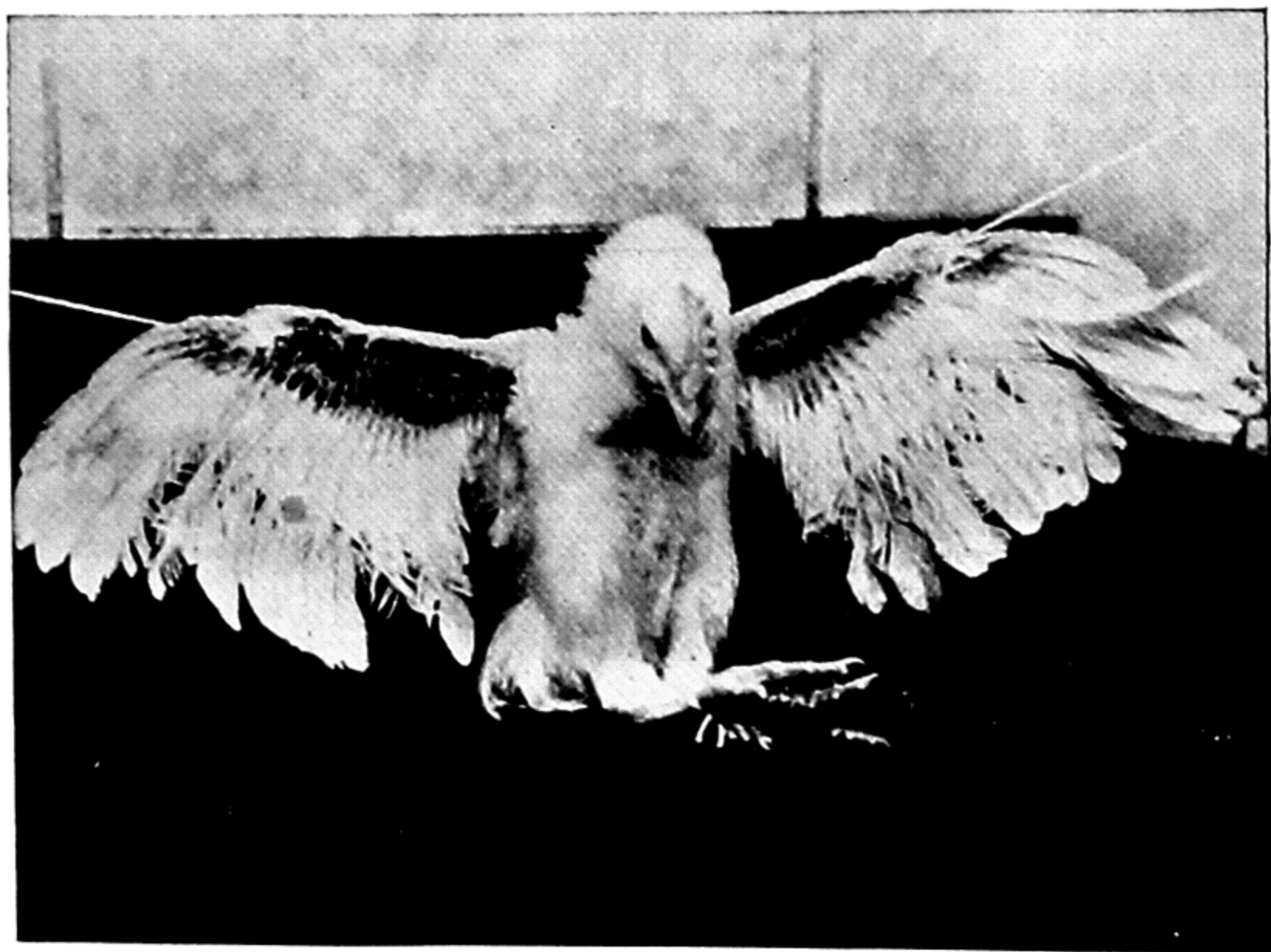
Whether conditions analogous to these occur in man is not clearly established as yet and we have no knowledge of the human requirement for this vitamin. As has been said, this vitamin occurs in such abundance in so many common foods that there is very little likelihood of a deficiency of it in average diets.

The most striking chemical property of the tocopherols is their antioxidant activity which explains their known sparing effect upon vitamin A, protecting it from oxidation in the alimentary tract and

in the cells of the body. Evidence has been obtained that a liberal supply of vitamin E makes it possible for animals to subsist on amounts of vitamin A otherwise too low. There is evidence also that vitamin A may exert a similar sparing effect on vitamin E.

Vitamin K

DISCOVERY. In 1934 Dam and Schonheyder, two Danish investigators, described a deficiency disease which they had produced in chicks which resembled scurvy in that subcutaneous and intramuscular hemorrhages developed but which was not prevented nor remedied by addition of ascorbic acid to the diet. The outstanding feature of the disease was the ease with which hemorrhage occurred. It was not long before Dam and his associates in Denmark and Almquist



(Courtesy of E. R. Squibb & Sons)

Fig. 102. Characteristic Hemorrhage Resulting from Deficiency of Vitamin K

and Stokstad in this country had obtained evidence that this disturbance in the blood-clotting power was due to the lack of a vitamin-like factor which Dam named vitamin K, thinking of it as a vitamin regu-

lating blood coagulation, "*koagulation*" in Danish. It was found that the decrease in coagulability of the blood was due to a lowered content of prothrombin, one of the substances required for normal blood clotting. This resulted in a lengthening of the time required for the blood to clot. Work on the isolation of the active substance was carried on intensively by many investigators in Europe and in this country with the result that by 1939 two vitamins K had been isolated, K₁ from alfalfa and K₂ from putrefied fish meal. These two vitamins are now known to be derivatives of the chemical compound naphthoquinone. Vitamin K₁ is present in green leaves while the vitamin K₂ form occurs in microorganisms. It is not known as yet in what form the vitamin must exist to carry out its functions in the body. The two vitamins are so much alike in activity that they are commonly referred to simply as vitamin K. Many chemically related compounds have been synthesized and tested for their anti-hemorrhagic activity and one of these is now on the market under the name of menadione.

FUNCTIONS. This vitamin is now known to be intimately associated with normal functioning of the liver as well as with normal clotting of the blood. Apparently this vitamin is not stored in the body to any great extent and the small amount that is stored is held in the liver so that injury to the liver may interfere with storing the vitamin and thus bring about a reduction in the prothrombin of the blood. Clinically it is frequently found that in diseases of the liver the prothrombin of the blood is abnormally low. If, in such cases, the liver damage is severe, administration of vitamin K is usually without effect.

If for any reason there is a lack of bile in the intestines, as in obstructive jaundice, for example, vitamin K is not adequately absorbed and prothrombin is lowered. Patients suffering in this way often die of hemorrhage if they have to undergo operation. Since the recognition of vitamin K the death rate in these cases has been greatly reduced by the use of the vitamin with bile salts. As little as 1 or 2 milligrams per day brings about a very rapid response in the prothrombin level. It has been suggested that in such disturbances the vitamin should always be given for a few days before operation and continued for some days after operation according to the change in prothrombin level.

Another condition which has been greatly benefited by the use

Other Vitamins

of vitamin K is that of the low prothrombin level commonly found in the blood of newborn infants, predisposing them to hemorrhage resulting in death. There are now many reports in the medical literature of striking success in reducing the death rate from hemorrhage in newborn infants by giving vitamin K either to the mother prior to the birth of the baby or to the baby immediately after birth. It is now recommended that a daily dose of 1 milligram of the vitamin be given to the mother during the last month of pregnancy.

In what way vitamin K brings about the formation of prothrombin is not known as yet, but it is well established that deficiency of it from any cause results in a low prothrombin level which can be corrected, as has been said, by administration of the vitamin except in those cases in which the liver is severely damaged.

SOURCES. There is some evidence that vitamin K may be synthesized by microorganisms normally present in the intestines, so that small amounts may be obtained in this way, but the vitamin is so widely distributed among different kinds of food that there seems to be little likelihood of a dietary deficiency of it. The green leaf vegetables, tomatoes, cauliflower, egg yolk, soybean oil, and liver are all good sources of this vitamin.

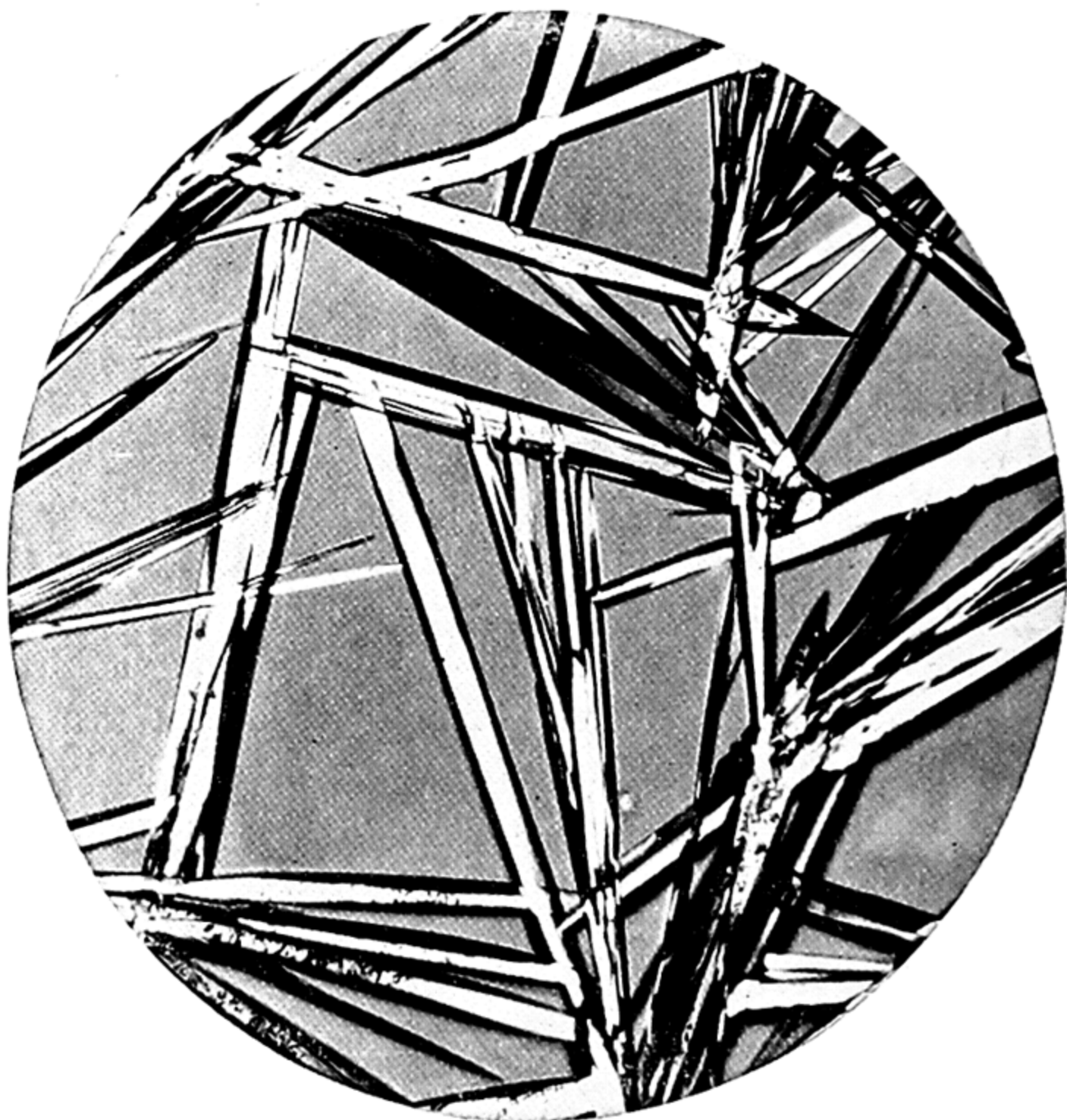
REQUIREMENT. Human requirement for this vitamin has not been determined as yet. However, Sells, Walker, and Owen have suggested that the daily requirement of the infant is about 1 microgram.

Vitamin B₆

The name vitamin B₆ was originally applied by György, in 1934, to a factor essential for rats which was distinct from the vitamins B₁ and B₂ (now called thiamine and riboflavin respectively). Lack of it in the diet of the rat resulted in a specific dermatitis or acrodynia. In 1938 a crystalline compound which was found to cure these symptoms was isolated almost simultaneously in five different laboratories, and in 1939 Harris and Folkers reported that they had synthesized it. The name pyridoxine was given to the compound and it was called either vitamin B₆ or pyridoxine.

In 1942 Snell and his associates reported finding that both rats and human beings converted pyridoxine to one or more substances having greater potency for promoting the growth of lactic acid bacteria than pyridoxine itself. This led to the synthesis of two compounds, pyridoxal and pyridoxamine, which were found to be highly

active for lactic acid bacteria. Since all three of these compounds occur naturally the term vitamin B₆ is now used for the group.



(Courtesy of Merck & Co., Inc.)

Fig. 103. Crystals of Vitamin B₆.

FUNCTIONS. Vitamin B₆ has been found essential for normal nutrition in all animals investigated thus far, although different species show different effects of a deficiency of the vitamin. Rats, as has been said, develop a dermatitis; in dogs and swine severe anemia results; hamsters show marked changes in the hair coat as do cattle; and monkeys exhibit a variety of effects, among them, fissuring of the epithelium of the hands and feet, severe anemia, and sclerotic lesions in the arteries.

The first attempts to produce vitamin B₆ deficiency in human beings resulted unsatisfactorily due to difficulties in removing all three forms completely from the diet. Recently, however, Vilter and his associates have reported production of the deficiency in man by feed-

ing desoxypyridoxine, a chemical analogue of pyridoxine which inhibits its activity. Of a group of 50 subjects suffering from various chronic diseases 30 were fed a diet low in B complex vitamins while



(Courtesy of Merck & Co., Inc.)

Fig. 104. Rat Showing Effects of Vitamin B₆ Deficiency

20 continued on the regular hospital diet. All received desoxypyridoxine in varying dosages. Thirty-four of the 50 subjects developed symptoms considered to be signs of vitamin B₆ deficiency. The most common sign was a seborrheic dermatitis occurring about the eyes, in the eyebrows, and at the angles of the mouth. Other results were changes in the tongue and membranes of the mouth very much like those occurring in pellagrins, and cheilosis, conjunctivitis, and angular stomatitis such as are seen in riboflavin-deficient subjects. Treatment with pyridoxine, pyridoxal, or pyridoxamine, either orally or parenterally, was effective in clearing up these symptoms. It was

found that as little as 5 milligrams of pyridoxine would cause healing of lesions resulting from feeding as much as 200 milligrams of desoxypyridoxine.

These investigators also reported that a pyridoxine ointment applied to the skin lesions brought about healing and that when they applied the ointment over larger areas of the skin other clinical symptoms responded. This would indicate that the vitamin was absorbed through the skin and utilized in the body. Another interesting finding was that the metabolism of the amino acid tryptophan is abnormal in human vitamin B₆ deficiency just as it is in animals. It is known that vitamin B₆ occurs in several enzyme systems in the body which are essential to the normal metabolism of proteins and amino acids. These findings seem to prove without question that vitamin B₆ is required in the diet of man.

It has been reported that nervous irritability and convulsive seizures in infants in the age range six weeks to six months who were kept on a proprietary milk formula without any supplements have responded dramatically to treatment with vitamin B₆, indicating that the disturbances were due to a deficiency of the vitamin in the milk formula. It is thought that the vitamin was lost in the process of preparation, and manufacturers are now correcting this.

SOURCES. For determination of vitamin B₆ in foods three procedures have been developed—chemical, biological, and microbiologic. The chemical methods are not as yet satisfactory since they were developed before it was known that the vitamin existed in different forms. The biologic assay with rats is thus far the generally preferred method, but microbiologic methods are being developed which give values agreeing well with those obtained by the rat assay method. It is reported that liver, yeast, rice bran, milk, cereals, legumes, meats, and fresh vegetables are good sources of the vitamin.

REQUIREMENT. Human requirement for pyridoxine is not yet accurately known. Balance studies cannot be depended upon to give the answer because of our lack of knowledge concerning the synthesis of the vitamin by intestinal flora. Only a rough estimate can be made from results obtained on animals and Vilter's work. The Food and Nutrition Board of the National Research Council considers that such evidence as is available indicates that the daily intake should be from 1 to 2 milligrams. Ordinary mixed diets can be depended upon to furnish such amounts.

Pantothenic Acid

Pantothenic acid was identified in 1933 by R. J. Williams as a substance essential to the growth of yeast. The name pantothenic is derived from the Greek, meaning occurring everywhere. Williams gave the acid this name because of its widespread occurrence in living tissues of all kinds which seemed to him to indicate that it must be of fundamental importance. In 1939 Elvehjem and his co-workers at the University of Wisconsin and Jukes of the University of California, working independently of each other, demonstrated that the "chick dermatitis factor" which they had been trying to identify was evidently pantothenic acid, which confirmed Williams' feeling that the acid was a vitamin important in animal nutrition. The synthesis of the acid was accomplished in 1940 and since then the pure acid or its calcium salt has been widely used in research laboratories. Williams has suggested the shorter name pantothen for this vitamin.

FUNCTIONS. When rats are placed on diets low in this vitamin they fail to grow normally and are found, on autopsy, to have suffered injury to the cortex of the adrenal glands. Graying of the hair has been observed on these diets when black rats are used and restoration of color when the missing vitamin was introduced into the food mixture. There are, however, contradictory results concerning this.

In dogs the Wisconsin workers found deficiency of pantothenic acid to be characterized by a sudden collapse of the animals which on autopsy revealed fatty livers and abnormalities in the intestines. Other investigators have reported disturbances of the nervous system in chicks and pigs on diets deficient in this vitamin. In all animals thus far studied deficiency of this vitamin has resulted in severe disturbances followed by death.

Little is known as yet about the significance of pantothenic acid



(Courtesy of Hoffmann-La Roche, Inc.)

Fig. 105. Crystals of Calcium Pantothenate

for the human being. Spies and his associates concluded from their studies of the pantothenic acid content of the blood of human beings on diets low in the vitamin that it is essential to normal human nutrition, but thus far no specific symptoms of its deficiency have been reported in man. Spies and his co-workers believe that the functioning of pantothenic acid may be related to that of riboflavin since they found on administering calcium pantothenate to patients showing symptoms of riboflavin deficiency an increase in the concentration of both pantothenic acid and riboflavin in the blood and also that injections of riboflavin caused increases in both.

Ralli has reported that pantothenic acid is apparently important in offsetting stress conditions in human subjects. She found that large doses (10 grams per day for six days) of calcium pantothenate cleared up some of the blood and urinary disturbances resulting from immersing young men in cold water. Glusman and Vernon have reported independently a possible relationship of pantothenic acid to the "burning feet syndrome" seen in Japanese prisoners-of-war. It had already been shown that this condition did not improve on administration of either thiamine or niacin. In another study of this condition Gopalan reported definite improvement in ten patients treated with calcium pantothenate. Attempts to induce true pantothenic acid deficiency in human beings have not as yet been entirely successful.

Such evidence as we have concerning the part played by pantothenic acid in human nutrition makes it practically certain that it is a required vitamin. It is known to be a part of coenzyme A. A is for acetylation which is a step in the chemical processes of normal utilization of carbohydrates, fatty acids, sterols, etc., in the body. Earlier reports that pantothenic acid prevented graying of hair in man have been contradicted by the results of later studies.

Pantothenic acid appears to be associated with ascorbic acid in the rat. Weanling rats have been maintained on diets deficient in pantothenate for comparatively long periods of time when their diet contained 2 per cent of ascorbic acid. It has also been reported that there is apparently an interrelationship between pantothenic acid and the metabolism of copper in the rat since the copper content of the skin was found to be increased on a diet lacking pantothenate.

MEASUREMENT AND SOURCES. The pantothenic acid of foods has been measured by means of growth experiments with chicks and rats

Other Vitamins

and by the use of microorganisms which require the acid. Liver, eggs, and dried yeast have been found to be especially good sources of the vitamin; skim milk, broccoli, cauliflower, potatoes (white and sweet), tomatoes, and molasses are classified as fair sources; whole milk and fresh fruits are somewhat poorer sources. Some canned foods have been studied. Of these, fish products were the best while asparagus, corn, and peas were only fair sources. In the cooking of meats a loss of one-third of the vitamin took place but only slight losses occurred in cooking vegetables. A loss of 57 per cent of the vitamin in wheat may take place in the manufacturing of patent flour. Some of these statements may need to be revised as better methods of determination are developed. It has been estimated that a good diet furnishing 2,500 calories contains approximately 10 milligrams of pantothenic acid.

REQUIREMENT. Human requirement for this vitamin is not accurately known as yet. From studies that have been made on normal human beings, the daily requirement is thought to be between 6 and 8 milligrams. It has been estimated that the amount of pantothenic acid consumed daily on a good diet furnishing 2,500 calories is approximately 10 milligrams.

Biotin

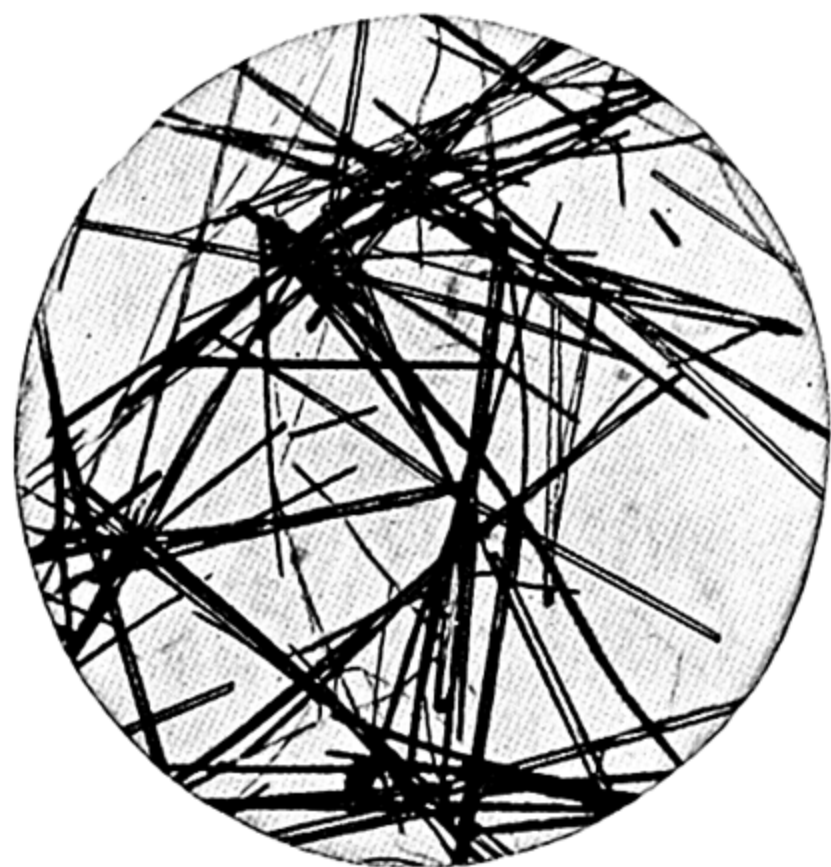
Biotin was first isolated in 1936 by Professors Kögl and Tonnies of Utrecht, Holland. Through the cooperative efforts of two laboratories, those of Professor duVigneaud at Cornell University Medical College and Professor Paul Györgyi at the Western Reserve University School of Medicine, its structure was established in the fall of 1942 and its synthesis accomplished in the spring of 1943.

FUNCTIONS. Recognition of biotin as a dietary essential resulted from studies of a condition produced in rats when they were fed diets containing high amounts of raw egg white. These animals developed among other symptoms a severe dermatitis, skin hemorrhages, edema, signs of nervous disturbances, some anemia, and suffered complete loss of hair. If the egg white was cooked no injury developed. It was found in the course of these studies that feeding very large amounts of the vitamin B complex prevented this condition and also cured it when it had developed. In 1941 Györgyi, Rose, Eakin, Snell, and Williams discovered in egg white a protein which they named avidalbumin (later changed to avidin) which has the property of uniting

with biotin to form a product which cannot be absorbed from the intestines and is, therefore, excreted in the feces. The avidin thus brings about the same result as a biotin-deficient diet would produce and so the symptoms of "egg white injury" are really those of biotin

deficiency. Nielsen and Elvehjem found that feeding an amount of biotin in excess of that which unites with the avidin cured the egg white injury.

Dr. Sydenstricker and his co-workers at the University of Georgia Medical School fed four human volunteer subjects a diet low in biotin and high in egg white but complete in all other known essentials except possibly inositol and para-aminobenzoic acid. Dermatitis developed on hands, arms, and legs, some changes in the tongue occurred, nervous symptoms very similar



(Courtesy of Dr. Vincent du Vigneaud and the Journal of Biological Chemistry)

Fig. 106. Crystals of Biotin

to those seen in thiamine deficiency appeared, loss of appetite resulted, and a peculiar grayish pallor of the skin developed. The hemoglobin content of the blood and the number and size of red blood cells decreased. Administration of iron did not remedy this condition. Prompt relief of all symptoms was brought about by administration of a concentrate of biotin. These observations indicate that biotin plays a role in normal human nutrition. It apparently plays an important part in intermediary metabolism, having been recognized as a coenzyme in several processes.

MEASUREMENT AND SOURCES. This vitamin can be determined by microbiological methods. It is found widely distributed in food materials. Egg, liver, kidney, yeast, most fresh vegetables, several fruits, and milk have been reported as good sources.

REQUIREMENT. Human requirement for this vitamin has not been established. It is difficult to establish because large amounts may be supplied by intestinal bacteria. Average human diets easily supply adequate amounts.

Choline

Choline has been known for many years as a part of lecithin, a substance occurring in the body which is closely related chemically to fat, but it was not until 1932 that evidence was obtained of its having any function in nutrition.

FUNCTIONS. Best of the University of Toronto reported at that time that the fatty livers which regularly developed in depancreatized dogs were prevented by administration of choline. That choline has a specific relation to the metabolism of fat has now been demonstrated in rats as well as in dogs. In addition to fatty livers, Griffith has also noted in rats on choline-deficient diets the occurrence of hemorrhages in the kidneys and the eyes, enlargement of the spleen, and a decrease in size of the thymus gland. Sure reports that choline is essential for normal lactation in the adult rat and prevents a certain type of paralysis in the suckling young. Several investigators have reported that on choline-deficient diets rats, dogs, and chicks fail to grow normally. Jukes finds that, in addition to adequate amounts of manganese, choline is required to prevent a condition known as perosis or slipped tendon in young turkeys.

DEFICIENCY IN MAN. Direct evidence of disease in man due to choline deficiency is lacking, but there are a few reports from clinicians that the cirrhosis of the liver which frequently occurs in cases of chronic alcoholism may well be the direct result of choline deficiency due to replacement of much of the food of the patient by alcohol. It has been found that dietary treatment with choline brought about improvement. It should be noted, however, that not many such cases have been reported. More well-controlled cases treated in this way are needed.

SOURCES. It is difficult for various reasons to determine accurately the choline content of foods. Since lecithin contains choline, foods containing it may be considered good sources of choline. The best dietary source is egg yolk. Dried yeast, brain, kidney, liver, pancreas, and soybean meal are good sources. Most human diets probably furnish enough choline to meet the usual needs for the vitamin.

REQUIREMENT. The choline requirement is difficult to determine because the amount depends upon the content of betaine and methionine in the diet. Most of the synthetic rations used for experi-

mental work with animals contain 100 milligrams of choline per 100 grams. From the results obtained with such amounts it is thought that the human requirement is less than 500 milligrams per day. It is estimated that the average human dietary furnishes 250 to 600 milligrams per day.

Inositol

Inositol, a component part of the well-known substance phytin, is a sweet-tasting, crystalline substance which in the animal body is found in muscle. It also occurs in brain tissue, red blood cells, and eye tissues. It is found in plants in the free form and in phytin.

FUNCTIONS. That it plays a part in animal nutrition was first reported in 1940 by Woolley who isolated it from liver and found that it caused recovery of hair in mice which had lost their hair on certain diets. Since then other workers have reported in rats a growth response, cure of so-called spectacled eye, and evidence that it is required for normal lactation. In dogs injection of inositol has been found to increase the motility of the intestines, and in chicks a stimulation of growth was obtained when the substance was added to a synthetic diet. It has been found to have important relationships to the metabolism of fat and cholesterol. It has been reported that inositol may improve the action of tocopherol in the treatment of progressive muscle dystrophy.

MEASUREMENT AND SOURCES. Inositol in tissues and foods is determined microbiologically using a specific strain of yeast as the test organism. Grains, yeast, brain, heart, kidney, muscle, and spleen have been found rich in inositol.

REQUIREMENT. The requirement for inositol is not known as yet, but it has been suggested by R. J. Williams that 1 gram daily is a "safe" level of intake.

Folic Acid (Folacin)

In 1945 Day and his associates reported evidence that a substance previously unknown was required by the monkey. They proposed calling it vitamin M (for monkey). Other workers, because it was found in green leaves, called it folic acid. When it was isolated in pure form and its formula established it was found to be pteroyl-glutamic acid. Further investigation has shown that there may be one, three, or seven glutamic acid radicals in the molecule. Also

some forms which are combinations of pteroylglutamic acid with other compounds are known to occur. All of these forms may be referred to as the folic acid group. The American Institute of Nutrition has now adopted the name folacin for folic acid or pteroylglutamic acid.

FUNCTIONS. It has been found that folic acid is required for normal growth and blood formation in the chick, fox, mink, and monkey. Rats and dogs do not require it in the diet under conditions of normal activity of intestinal bacteria. The human being is like the rat and dog in this respect.

Folic acid deficiency in the chick also results in abnormal feather pigmentation. It is thought that this may be the result of abnormal metabolism of the amino acid, tyrosine, due to the folic acid deficiency, since it is known that folic acid is involved in tyrosine metabolism. It is also known to be involved in the metabolism of ascorbic acid in some way as shown by the finding that the monkey on a folic acid-deficient diet fails to become anemic if he is given sufficient quantities of ascorbic acid. It is of interest to note, however, that if the animal is made anemic by a diet low in both folic and ascorbic acids, only folic acid will bring the blood back to normal.

When synthetic folic acid became available it was tried on pernicious anemia patients with striking effect on the blood condition but none on the nervous condition. Anemias due to lack of iron do not respond to folic acid treatment. In the macrocytic anemias (those characterized by blood cells enlarged in size and fewer in number than normal), which occur rather commonly in infants and pregnant women and in sprue, folic acid proves highly effective.

MEASUREMENT AND SOURCES. The first attempts to determine the folic acid content of foods yielded unsatisfactory results because of not knowing about the bound forms of the vitamin which necessitate liberating the folic acid by certain enzymes in order to obtain the total amount. More recently, however, Toepfer of the United States



(Courtesy of Hoffman-La Roche, Inc.)

Fig. 107. Crystals of Folic Acid

Department of Agriculture has presented the results of determining the folic acid content of a large number of foods by improved quantitative methods. His results indicate that fresh, green, leafy vegetables, kidney, liver, whole grains, nuts, and fresh green vegetables such as asparagus, green beans, and peas may be considered good sources while most other foods are only fair or poor sources of the vitamin.

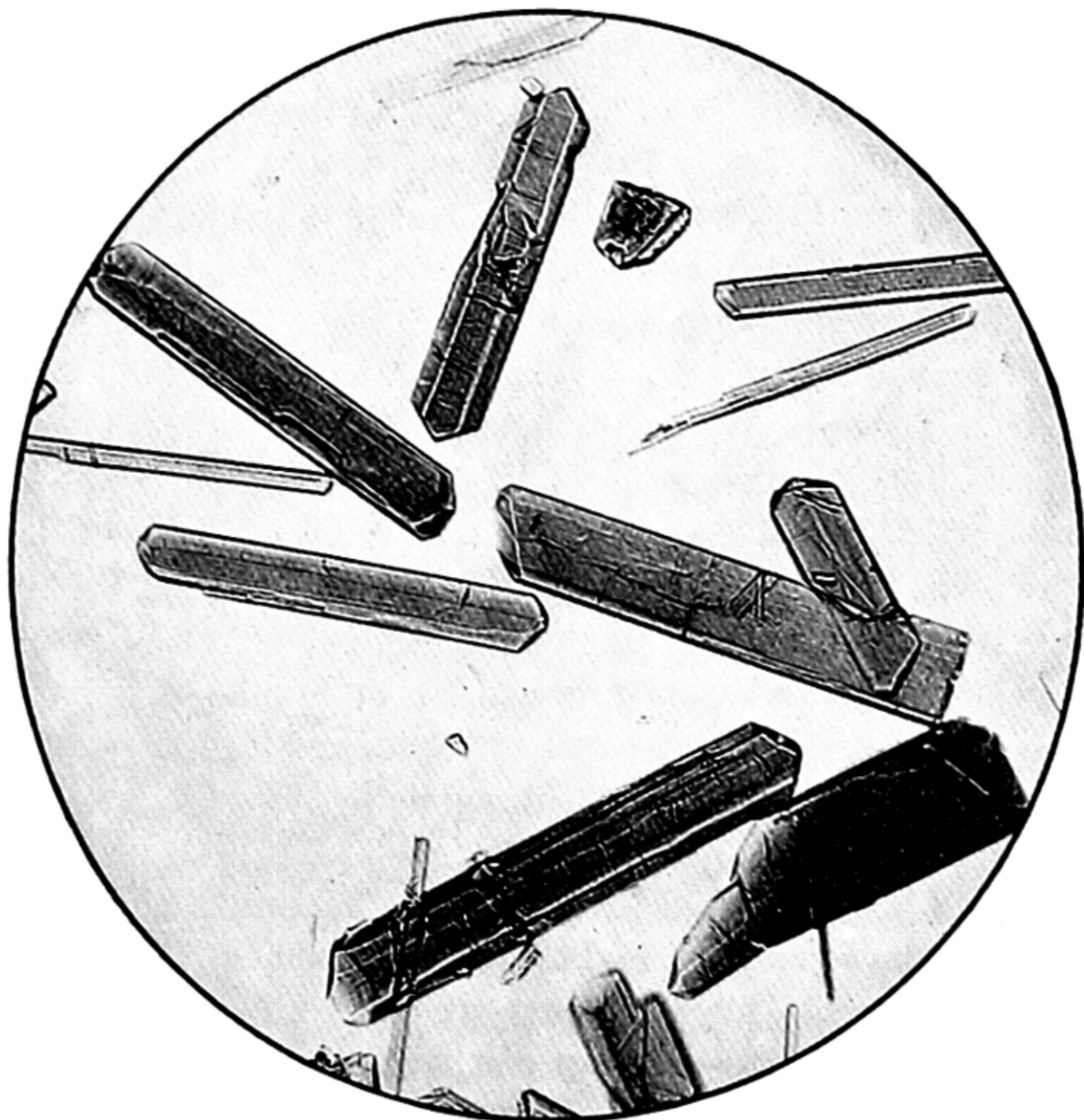
REQUIREMENT. Human requirement for this vitamin is not accurately known as yet. Studies of the requirement of chickens, monkeys, and turkeys, on a calorie basis, seem to indicate a requirement of less than 1 milligram per day for the human being. Synthesis of folic acid by intestinal bacteria seems to account for the difficulties encountered in attempts to establish the human requirement.

CITROVORUM FACTOR (CF). This substance is apparently formed in the body from folic acid (folacin) and appears to be the functional form or one of the functional forms of folic acid. A synthetic form of it not identical with the natural product is called folinic acid. Since organisms which require folic acid also respond to the citrovorum factor it might be expected that this factor would be effective in the same conditions as is folic acid. Some reports have been made on the results of using it therapeutically. Spies and his associates found that administering CF for ten days to patients with pernicious anemia, sprue, and nutritional anemia resulted in a maximum improvement in their blood. Other investigators have reported a hematologic response in pernicious anemia but not equal to that produced by vitamin B₁₂. All studies made thus far seem to indicate that folic acid has to be transformed to citrovorum factor within the living organism before it can carry out its catalytic functions.

Vitamin B₁₂ (Cyanocobalamin)

Minot and Murphy in 1926 reported finding that in their clinical practice pernicious anemia responded to treatment with whole liver or an extract of it. This announcement stimulated research in a number of laboratories on the fractionation of liver extracts with the object of isolating the active component. Finally, in 1948, Smith and Parker in England and Folkers and his associates in the United States reported simultaneously the isolation of a crystalline red substance containing cobalt and phosphorus which was effective in pernicious anemia. It was named vitamin B₁₂. In clinical tests daily dosages as small as one- to five-millionths of a gram injected intramuscularly

were effective in arresting the nervous disturbances in pernicious anemia as well as in restoring the blood to normal condition. The presence of cobalt in this compound was of special interest because it had already been established that pasturing ruminants on soils low in cobalt resulted in the disturbances referred to as the coast disease in Australia and New Zealand (see Chapter 11, Section 3).



(Courtesy of Merck & Co., Inc.)

Fig. 108. Crystals of Vitamin B₁₂

One molecule of this compound is now known to contain 63 atoms of carbon, 90 of hydrogen, 14 of oxygen, 14 of nitrogen, 1 of phosphorus, and 1 of cobalt. With the exception of protein molecules this molecule appears to be the heaviest and most complex thus far found in nature. In August, 1955, the structural formula of this complicated molecule was announced by two teams of investigators made up of workers at Oxford University, England, the University of California at Los Angeles, Princeton University, Cambridge Uni-

versity, England, and the Glaxo Laboratories of Middlesex, England. The research division of the Merck Laboratories and other groups also assisted in the work.

FUNCTIONS. Early in the studies of liver feeding in pernicious anemia it was found that mixtures of beef muscle and normal gastric juice brought about the same improvement in the blood picture as the liver. The gastric juice of anemia patients would not act in this way. This led to the conclusion that two factors were involved—an intrinsic factor in normal gastric juice and an extrinsic factor present in food. Castle proposed the theory that these two factors reacting with each other form an erythrocyte maturation factor. The efficacy of vitamin B₁₂ in treatment of pernicious anemia established it as the extrinsic factor. The intrinsic factor is still unidentified. Since it takes much larger dosages of vitamin B₁₂ if given by mouth than if injected intramuscularly, it is thought that the intrinsic factor promotes absorption of vitamin B₁₂, but how it does this is not known. Since vitamin B₁₂ is formed by the intestinal bacteria of pernicious anemia patients, just as it is in healthy individuals, it is thought that the fundamental defect in pernicious anemia may be a deficiency of the intrinsic factor which would result in lessened absorption of vitamin B₁₂.

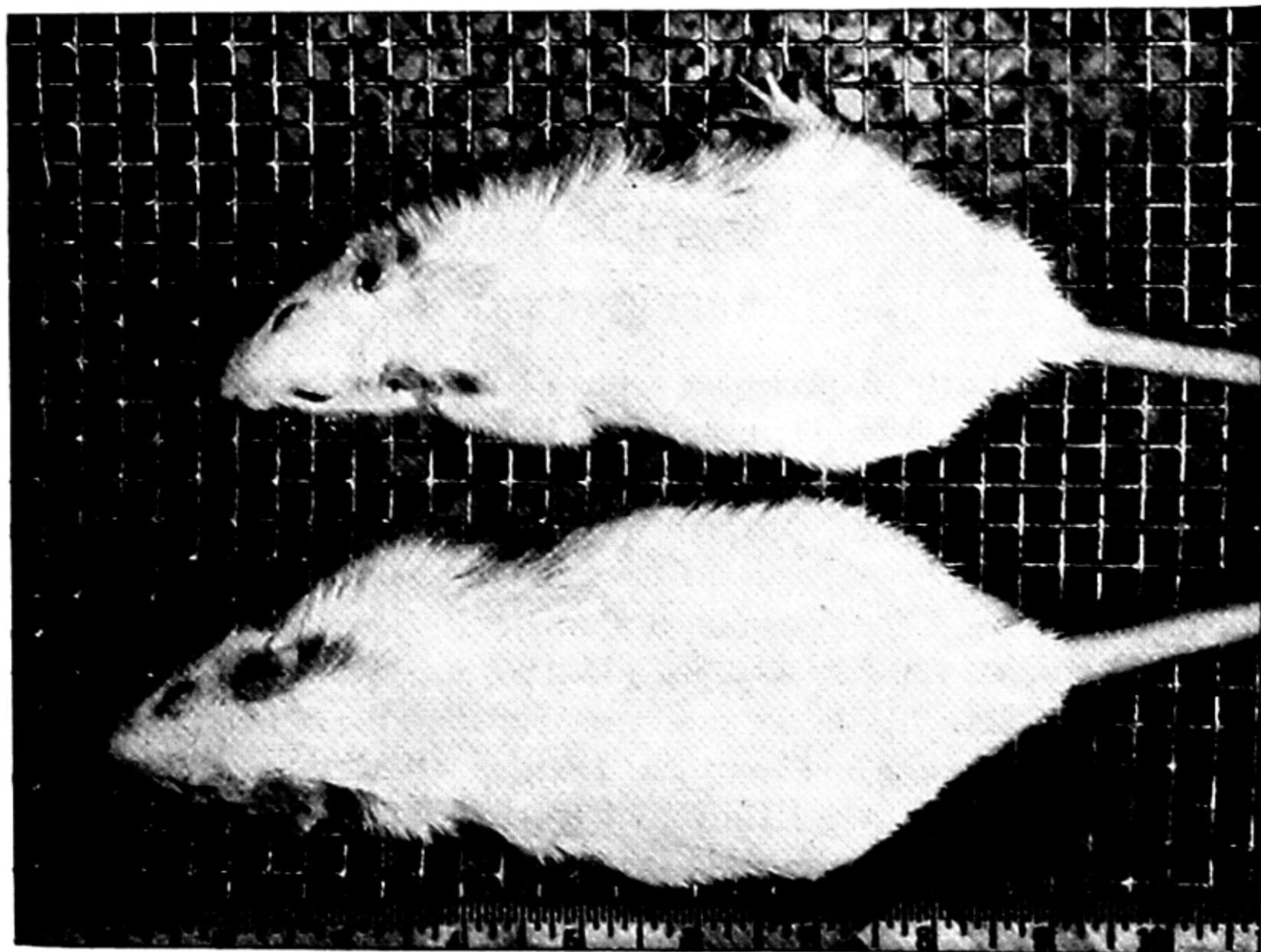
This vitamin has been reported to have growth-promoting activity for some microorganisms and for animals. There have also been reports that administering the vitamin resulted in a growth response in children who had not been growing at a normal rate, but other investigators have reported finding no improvement. More carefully controlled studies on larger numbers are needed.

Rats on a vitamin B₁₂-deficient diet were found to have decreased resistance to cold stress. When kept at temperatures close to freezing, they were found to need significantly greater amounts of the vitamin than when maintained at normal room temperature.

Evidence has been obtained that vitamin B₁₂ plays a part along with choline and folic acid in the metabolism of the amino acid, methionine. It has been found to exert a sparing effect upon choline.

Vitamin B₁₂ labeled with radioactive cobalt has been used in some studies of the metabolism of the vitamin. Oral dosages were administered to normal persons, pernicious anemia patients, and subjects suffering from various disorders. The normal persons excreted from 8 to 41 per cent of the cobalt in the feces while the pernicious anemia patients excreted from 48 to 100 per cent. Patients suffering from

such conditions as cardiac disease, cirrhosis of the liver, and rheumatoid arthritis ranged from 11 to 100 per cent. Administration of 100 milliliters of neutralized gastric juice to the pernicious anemia patients reduced the fecal radioactivity in some of them. Folic acid administration had no effect upon it.



(Courtesy of Merck & Co., Inc.)

Fig. 109. Two Rats—Lower Normal, Upper Showing Vitamin B₁₂ Deficiency

MEASUREMENT AND SOURCES. Assay methods for this vitamin are based upon its growth-promoting effect on certain bacteria, the rat, and the chick. The results obtained lead to the conclusion that the vitamin is not present in significant amounts in the higher green plants or in ordinary foods of vegetable origin. The richest food sources of those that have been tested are kidney, liver, eggs, milk, and muscle meats. Various seaweeds have been reported to be rich sources. It is suggested that these algae may be the source from which marine animals such as clams, oysters, other mollusks, and fish obtain the comparatively large amounts found in them. Various milks have been assayed for their content of the vitamin, giving results as follows (millimicrograms per milliliter): rat, 13.0; ewe,

7.0; cow, 2.3; sow, 1.7; goat, 0.9; human, 0.3. The low results for human milk are interesting in light of the fact that breast-fed infants are not known to show signs of vitamin B₁₂ deficiency. This doubtless means either that the infant's requirement is low or that it is born with stores which are adequate until the time comes for supplements. One pint of cow's milk contains approximately 1 microgram, an amount which produces good hematologic response when injected daily into pernicious anemia patients.

REQUIREMENT. The human requirement for this vitamin is not known as yet.

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Contributions to the Diet Made by Various Types of Food Materials

In previous chapters we have considered the essentials of an adequate diet and have found that they may be stated under five headings:

(1) Energy to meet the daily expenditure; with surplus for storage only when actually needed for growth or to build up an underweight adult.

(2) Protein in sufficient quantity to replace daily nitrogen loss, and to supply a liberal and complete assortment of indispensable amino acids, especially during growth.

(3) Mineral elements of many kinds, each with its own special function for which no other can be substituted, and all so related to the regulation of life processes as a whole that any failure of an adequate supply is likely to bring disaster, especially during growth.

(4) Vitamins, serving as regulators of metabolism and controlling the processes involved in maintenance, growth, and reproduction.

(5) Water, not only an important constituent of the body, but the carrier of food to the tissues and waste away from them, and otherwise important in the regulation of body processes.

These dietary essentials may be conveniently summarized according to their main functions in the following way:

(1) Food as a source of energy or fuel for the body machine:

Carbohydrates
Fats
Proteins

(2) Food as a source of material for the development and maintenance of body structure:

Proteins
Mineral Elements
Vitamins
Water

(3) Food as a means of coordinating and otherwise regulating body processes:

Amino Acids
Mineral Elements
Vitamins
Water

What Relation Has a Food to the Diet?

Having learned what types of nutriment are needed to keep the body in prime working condition, our next task is to consider what relationship individual food materials have to the diet as a whole. Few foods consist, as does cane sugar, of a single chemical substance. The novice in nutrition is like a person who has never seen a watch: when he looks at it for the first time, all he observes is a shiny case with a glass front covering a dial bearing numbers from one to twelve, and hands which revolve upon it. How different the mental picture of the watchmaker, who with his mind's eye looks through the metal case as if it were transparent and beholds delicate wheels, jewels, screws, and springs, all related to each other and harmoniously contributing to the beautifully coordinated movement of the whole! So it is with any article of food. To a person who has not studied nutrition, an orange is a bright-colored, fragrant globe inside of which are neatly packed sections yielding a delicious, juicy pulp. It is just something good to eat. So are cake and pie and chocolate creams. But to the one who has learned to think in terms of nutritive value, an orange is a food shop. First, there is water—much of it; it constitutes nearly nine-tenths of the weight of the peeled fruit. Then there is sugar, amounting to one-tenth of the edible portion; a small

portion of protein; scarcely a trace of fat; a galaxy of mineral elements, including calcium, phosphorus, sulfur, iron, sodium, potassium, etc.; and lastly, vitamins, among which are ascorbic acid, thiamine, vitamin A, and riboflavin.

Is an orange like a potato? Who would think so, to see or taste them? Yet they have much in common. The potato contains nearly as much water as the orange. It has starch where the orange has sugar, but these are both carbohydrates, serving interchangeably as body fuel. Protein is only slightly more plentiful in the potato, and fat is found as a mere trace in both. The same mineral elements and vitamins may be found, though in different proportions.

If we set out to eat the same number of calories from oranges as from potatoes we may make some interesting discoveries. Very likely we shall be able to eat day after day, without any digestive discomfort, more potatoes than oranges. The fact that oranges are acid and potatoes are not may make some difference to our stomachs, but once safely through the digestive tract even the difference in acidity disappears, for the acid of the orange is quickly burned away.

Neither food will furnish protein adequate for growth. The amount of each necessary to furnish enough calories might prove something of a tax on appetite if not on digestion, as it would take in the neighborhood of thirty-four medium oranges or two dozen medium potatoes for a rather sedentary man for a day; and the potatoes would not furnish enough calcium or vitamin A. At last we should be driven to other foods for the compounding of a ration ideal in all respects.

Race Experience Does Not Insure Good Nutrition

Experience has taught the human race a great deal of practical value about diet but it is no guarantee of an ideal one. Some people with no scientific knowledge of nutrition are so situated as to be well nourished on their natural diet. McCarrison cited certain isolated peoples in the Himalayas, whom he found remarkably vigorous, although living on what would seem to be a much restricted diet. "For nine years of my professional life," he said, "my duties lay in a remote part of the Himalayas, where there are located several isolated races, far removed from the refinement of civilization. Certain of these races are of magnificent physique, preserving until late in life the characters of youth; they are unusually fertile and long

lived, and endowed with nervous systems of notable stability. Their longevity and fertility were, in the case of one of them, matters of such concern to the ruling chief that he took me to task for what he considered my ridiculous eagerness to prolong the lives of the ancients of his people, among whom were many of my patients. The operation for senile cataract appeared to him a waste of my economic opportunities, and he tentatively suggested instead the introduction of some form of lethal chamber designed to remove from his realms those who by reason of their age and infirmity were no longer of use to the community.”¹ These people lived on a very frugal diet, consisting of apricots which they sun dried for winter use, vegetables, and goat’s milk; goats were the only livestock and while butter was made from the milk, goat’s meat was eaten only on feast days.

Mellanby described another isolated group on the Island of Lewis in the Hebrides, whose houses were unsanitary, being windowless and full of smoke, and whose children got comparatively little sunlight; yet the death rate of their infants was very low and rickets practically unknown. Their diet consisted mainly of milk, oatmeal, potatoes, turnips, and fish. A staple article of diet was cod’s head stuffed with a mixture of oatmeal, milk, and cod livers. Such a diet would seem very limited to an average American, yet was capable of a great saving of infant lives.

Another interesting study of the relationship between man’s natural diet and his physical status was reported in 1931 by Orr and Gilks of the Rowett Research Institute, Aberdeen, Scotland. Two African tribes living side by side were found to have very different dietary customs. The Masai, a pastoral people whose sole occupation was that of tending their herds, lived largely on meat, milk, and blood drawn from the living animal after puncturing the jugular vein with an arrow. Various roots and barks were used for “teas,” taken with boiled meat or milk. The pregnant women were sent into the bush to eat berries.

The Akikuyu subsisted chiefly on cereals, tubers, plants, legumes, and green leaves. Large herds of goats were used as currency, not as a source of milk and meat. The men lived chiefly on maize, sweet potatoes, or other cereals and tubers. Young children of both sexes up to the age of five years were given edible earths from salt licks and the ashes of certain swamp plants. The source of supply of one

¹ McCarrison, Robert. “Faulty Food in Relation to Gastro-Intestinal Disorders.” *Journal of the American Medical Association*, Vol. 78, page 1 (1922).

of these earths with an especially high calcium content was at one time in the Masai country. The Akikuyu were then in the habit of making raids and fighting for this salt. They said their cattle were fatter, bred better, and were more resistant to disease when they had a supply of "Gitirikani earth." The girls used these special sources of minerals through adult life and the women had virtually a monopoly of some kinds of green leaves also rich in calcium. A certain type of millet about 16 times as rich in calcium as ordinary millet was reserved for them during pregnancy and lactation. This was believed to improve the milk flow. The Akikuyu man's diet was exceedingly low in calcium and even when supplemented for children with the edible earths and plant ashes it was not adequate for their best growth. During the first month of life the Akikuyu infants were only about half a pound lighter than English babies. For ten months thereafter they grew at about the same rate; after that the Akikuyu grew much more slowly and at 30 months were about 8 pounds lighter than the English. The full-grown Masai male was on the average 5 inches taller and 23 pounds heavier than the full-grown Akikuyu, and his muscular strength was 50 per cent greater. Among the Akikuyu, deformities of the bones, dental caries, spongy gums, anemia, pulmonary diseases, tropical ulcer, and other diseases fostered by poor nutrition were much more prevalent than among their neighbors with a better diet. A study of the children up to eight years of age showed that while the general physical condition of the Masai boys and girls was rated as "very good" in over 60 per cent of the cases there were only 7 per cent of the Akikuyu boys and 29 per cent of the girls so rated. The diet of the Akikuyu affords striking evidence that race experience does not always lead to the best dietary practices. The calcium obtained by this tribe in too small amounts and with difficulty from the plant ashes and earths was easily secured by their neighbors from milk, with the added advantage that it was more efficiently utilized. The value of a better diet was also shown in the better health of the women and girls as compared with that of the men and boys. In their physical examination only 18 per cent of the girls under eight years of age were judged "poor, bad, or very bad"; 44 per cent of the boys were so rated.²

While America is still the land of opportunity, and food is suffi-

² Orr, J. B., and Gilks, J. L. *Studies of Nutrition: The Physique and Health of Two African Tribes*. Medical Research Council, Special Report Series, No. 155. His Majesty's Stationery Office, London (1931).

ciently plentiful and varied to prevent general outbreaks of deficiency diseases, we have to face the fact that the nutritional state of our American school children is not ideal; our draft and selective service records revealed a low state of vigor in the case of many of our young men. It should be a part of every child's education to learn what contributions the different kinds of food material make to this composite thing which we call diet, and to understand that a diet is something to be built, like a house; that just as an architect might specify stone for foundations, tile and stucco for walls, wood for interior finish, glass for windows, slate for roof, wire for electric lighting, brass for door knobs, each in quantities to suit his plan, so we must each have a plan for our diet which shall free us from the dangers of "hit and miss" eating.

Recommended Allowances and Nutritive Values Expressed in Shares

Our knowledge of the nutritive values of food is the result of the labors of many investigators in this field. Through the work of Atwater, Sherman, and many other chemists, we now have extensive tables, giving the results of hundreds of thousands of analyses of food materials for protein, fat, carbohydrate, water, mineral elements, and vitamins. With the establishment of nutrition laboratories in many countries under the leadership of the Food and Agriculture Organization of the United Nations and many other organizations, our knowledge of the composition of foods in many parts of the world has been greatly extended. All of these sources have been used in preparing Tables II and IV of the Appendix. To the beginner these tables may seem somewhat confusing, but it is possible for practical purposes to state the nutritive values of foods in a simpler way which is explained in the following paragraphs.

The feasibility of thinking of the energy values of foods in terms of 100-calorie portions has already been stressed in Chapter 5. The Food and Nutrition Board of the National Research Council has recommended 3200 calories as the daily energy requirement of the "reference" man. Each 100 calories would then be $\frac{1}{32}$ of the day's requirement.

Let us now think of a diet requiring 3,200 calories as made up of 32 such portions. As we have already seen, the other allowances

recommended for the "reference man," age twenty-five, and weighing 65 kilograms, are as follows:

Protein, 65 grams for the 65 kilogram man, or 2.03 grams per 100 calories

Calcium, 0.8 gram, or 0.025 gram (25 milligrams) per 100 calories

Iron, 12 milligrams, or 0.38 milligram per 100 calories

Vitamin A, 5,000 International Units, or 156 I.U. per 100 calories

Thiamine, 1.6 milligrams, or 0.05 milligram per 100 calories

Ascorbic acid, 75 milligrams, or 2.34 milligrams per 100 calories

Riboflavin, 1.6 milligrams, or 0.05 milligram per 100 calories

In an adequate diet we may think of each 100 calories as constituting a cross section of the day's ration and carrying its own quota or share of each of the above-mentioned substances. We may then call $\frac{1}{32}$ of the daily allowance of each nutrient one share of that nutrient. The values for each of these would then be as follows:

One share of energy	= 100 calories
One share of protein	= 2.03 grams
One share of calcium	= 25 milligrams
One share of iron	= 0.38 milligram
One share of vitamin A	= 156 International Units
One share of thiamine	= 0.05 milligram
One share of ascorbic acid	= 2.34 milligrams
One share of riboflavin	= 0.05 milligram

The dietary allowances for all age levels given in Table III(a) (Appendix) can now be expressed in shares simply by dividing the recommended amount of each nutrient by the value of one share of that nutrient. This has been done for all the nutrients except niacin and vitamin D and the results tabulated in Table I(a). Share values for niacin have not been calculated because if a dietary furnishes adequate amounts of the other essentials it will undoubtedly provide sufficient niacin or its precursor, tryptophan. Vitamin D is not included in the tabulation because the requirements for other than infants, children, and pregnant and lactating women have not been established. Also, it occurs in relatively small amounts in only a few common foods so that fish liver oils or concentrates of them, or specially treated food such as vitamin D milk must be depended upon as sources.

Using the share value of each dietary essential, it is also a simple matter to determine the number of shares contributed by any food whose chemical composition is known, as the following calculation of share values for an orange will show. Choosing one large enough to yield 100 calories, the amount of each nutrient and its share value will be as follows:

100 calories	$\div 100 = 1.0$ calorie share
2.0 grams of protein	$\div 2.03 = 1.0$ protein share
73 milligrams of calcium	$\div 25 = 2.9$ calcium shares
0.9 milligram of iron	$\div 0.38 = 2.4$ iron shares
500 I.U. of vitamin A	$\div 156 = 3.2$ vitamin A shares
0.18 milligram of thiamine	$\div 0.05 = 3.6$ thiamine shares
118 milligrams of ascorbic acid	$\div 2.34 = 50.4$ ascorbic acid shares
0.11 milligram of riboflavin	$\div 0.05 = 2.2$ riboflavin shares

It will not be necessary to make such calculations hereafter as the share values of all the foods listed in Table IV (Appendix) have been obtained in this way and are given in Table II (Appendix). It will be noted that using shares greatly simplifies the calculations of food values. It is easier to find the nutritive value of two oranges by observing that it will be two times the share values than by multiplying the calories, grams, milligrams, and International Units by two. Whenever the actual weight of a nutrient needs to be known, the total number of shares has only to be multiplied by the standard value of one share. Another advantage of using shares is that comparisons can be made so easily (1) of foods with each other, (2) of the contributions of individual foods in a dietary with the total amounts of the various nutrients, and (3) of the contributions of a dietary with the recommended allowances for the individual, whether man, woman, or child. These comparisons can be made at a glance without any calculating.

The contributions which different foods make to the diet are more readily appreciated when presented in graphic form. In Fig. 110 are shown share values for an orange and a potato. The bars from left to right, representing the various dietary essentials, are in this and in succeeding figures given in the order listed in the legend, and the height of each bar corresponds to the share value listed for that essential. It will be noted that the bar representing ascorbic acid in

the orange is broken; this indicates that its full length would have to be greater—in this case more than half again as long. This device is used whenever the number of shares exceeds 32. In making such graphs on cross-section paper where each square represents one share, the bars can easily be widened to include as many squares as may be necessary, with more striking effect. Fuller presentation of the advantages of using shares and more detailed suggestions for presenting food values graphically will be found in Taylor's *Food Values in Shares and Weights*.

For Fig. 110 two food portions of the same energy value have been selected for consideration. Comparing their contributions of protein, it will be observed that both the orange and the potato just about take care of themselves, each contributing at least one protein share for each calorie share. Experimental work has shown that protein needs of adults, both animals and men, can be met by potato protein only, but that it will not support growth unless supplemented by some complete protein which makes good certain amino acid deficiencies. As the potato protein is easily supplemented with that of milk, eggs, or meat, it can be counted at its full value in a mixed diet.

By reference to Fig. 110 again, it will be noted that the orange is six times as rich in calcium as the potato. By combining the two, the deficiencies of one will be made good by the other. As sources of iron the two are about equal, both having at least twice as many shares of iron as of calories and thus more than meeting their quota. Together these two foods have 2.5 shares to contribute toward making good the iron deficiency of some other food.

The potato is not a good source of vitamin A, but the orange would make up its deficiency and have one share to spare. Both are good sources of thiamine. The outstanding contribution of ascorbic acid made by the orange may be seen at a glance. It will furnish more than half as much again as is required to meet the allowance set for the "reference man." The potato, while furnishing less than the orange per 100 calories, may be eaten regularly in larger amounts and so may make a very substantial contribution to the total ascorbic acid of the diet. Neither food is an important source of riboflavin, although together they furnish one share to the good.

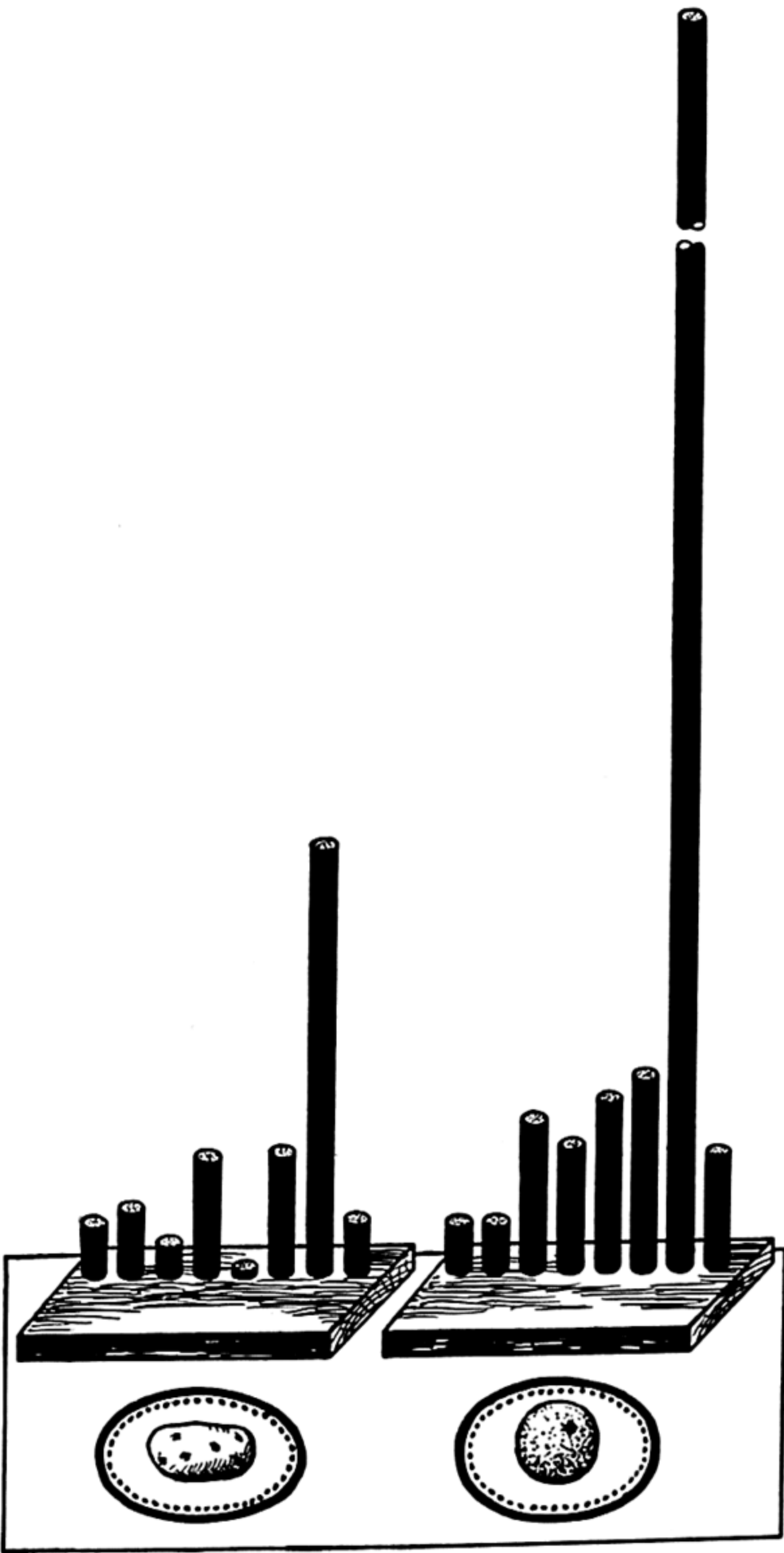


Fig. 110. A Comparison of the Shares Contributed by a Potato and an Orange

	Shares in Order on Blocks							
	Cal- ories	Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascor- bic Acid	Ribo- flavin
Potato, 1 med. baked	1.00	1.2	0.5	2.1	0.1	2.2	7.7	1.0
Orange, 1 large	1.00	1.0	2.9	2.4	3.2	3.6	50.4	2.2

Foods Grouped According to Nutritive Value

It would be far beyond the scope of this book to discuss a large number of individual foods in the same detail as the orange and potato but, fortunately, many foods are quite similar in their chemical composition and nutritive properties and may be considered in groups as follows:

(1) *Milk*, of all single food materials, contains the greatest assortment of nutritive substances and constitutes the foundation upon which an adequate diet can most safely and most easily be constructed.

(2) *The grains* are primarily sources of energy, and secondarily of protein—not always adequate by itself, but when properly supplemented, of great practical value. Only by special selection or in the “enriched” forms does this class of foodstuffs become important for mineral constituents or vitamins. Their most significant vitamin contribution is thiamine, present in the germ and less richly in the bran. They lack vitamin A and ascorbic acid and contain relatively small amounts of riboflavin.

(3) *Vegetables and fruits* are of greatest significance for their mineral constituents and vitamins. Both are irregularly distributed, but if such foods are taken in large enough quantities and embrace a wide range of varieties, there is a good chance of safety, provided a serving of a green and/or a yellow vegetable and a citrus fruit are included each day. Only certain members of the group are good sources of calories, and still fewer of proteins.

(4) *Meat, fish, poultry, eggs, cheese, and nuts* are of prime significance for their yield of proteins of excellent quality. Most members of this group, with the exception of very lean meats, are also good sources of energy because of the fat as well as the proteins which they provide. Meats and eggs are good sources of iron; meats, eggs, and cheese of riboflavin; and many of the cheeses of calcium. The yield of other minerals and vitamins varies with the different members of the group.

(5) *Fats* are primarily sources of calories in concentrated form. In certain cases they are also carriers of vitamins A and D.

(6) *Sugars*, like fats, are sources of calories. Pure sugars contribute nothing else. A few foods containing sugar in high concentration make other contributions of some significance.

In the following chapters the nutritive values of these various food groups will be discussed in more detail. In Table XVI in the Appendix will be found the working plans for the construction of adequate diets expressed in terms of percentages. The calories from each food group can be obtained from the percentage distribution given. The percentages have been worked out for children of different ages, adults, and family groups and are a great help in planning the day's food supply.

There are a number of ways in which foods can be grouped so that if a selection is made from each group an adequate diet will be achieved. The Basic Seven Groups suggested by the Bureau of Human Nutrition and Home Economics of the United States Department of Agriculture provide a grouping of foods as follows: (1) leafy, green, and yellow vegetables; (2) citrus fruit, tomatoes, and raw cabbage; (3) potatoes and other vegetables and fruits; (4) milk, cheese, and ice cream; (5) meat, poultry, fish, eggs, dried peas and beans; (6) bread, flour, cereals (whole grain or enriched); and (7) butter and fortified margarine. By following this plan many people have been guided to the selection of a more adequate diet.

In Canada, five groups of food have been worked out for their national food guide, the five groups serving their needs better than our seven groups. The five groups are as follows: (1) milk; (2) fruits, including citrus, tomatoes, apples, and berries; (3) vegetables, green and yellow, potatoes, turnips, and cabbage; (4) breads and cereals (whole wheat and enriched); and (5) meat, fish, eggs, and cheese.

The five food groups which have been worked out by the Department of Health for use in Puerto Rico are as follows: (1) milk, fresh, evaporated, or dried; (2) meat, fish, eggs, and legumes; (3) yellow and green vegetables, sweet potato, calabaza (pumpkin); (4) fruit, fresh domestic including citrus, papaya, mango, banana, and pineapple; and (5) rice, kidney beans, codfish, sugar, lard, fat, and coffee.

Each of these plans if carefully followed will assure an adequate diet. In planning such guides for a particular population group, foods selected for each group must be chosen from those (1) available, (2) of high nutritive value, (3) in keeping with native likes and dislikes, and (4) within the income level of the mass of the population.

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Milk and Cheese

Section 1. MILK

In 1912 Hopkins published the now classic curves shown in Fig. 53, illustrating the effect on a rat's growth of adding less than one-third of a teaspoonful of milk per day to a ration of purified food materials. From that time to the present, evidence has continued to accumulate regarding the unique place of milk in nutrition.

Osborne and Mendel found that milk deprived of its protein and fat enabled them to keep animals alive that otherwise would have died, and that milk proteins would promote growth when some others would not. Then vitamins A and thiamine were discovered in milk, and Sherman and Hawley demonstrated the superiority of milk as a source of calcium. The editor of the *Journal of the American Medical Association* commented on this as follows: "The dietary rule of a quart of milk each day for every child is much more than a precept based on individual opinions or drawn by analogy from the results of feeding experiments with lower animals; it now rests on scientific evidence obtained by extensive and intensive experiments directly upon the children themselves." Later research led to the discovery of riboflavin, another factor in the maintenance of that superior state of nutrition which McCollum has called "the preservation of the characteristics of youth." It is present in milk to a degree which makes it an excellent complement to the cereals which are so generally deficient in riboflavin.

The dependability of milk as a source of many of the essentials of normal nutrition was fully demonstrated by Sherman and his associates. On a diet consisting of one-sixth part dried whole milk

and five-sixths ground whole wheat, certain rat families prospered through more than 80 generations. Yet increasing the proportion of milk in this obviously efficient diet from one-sixth to one-third resulted in striking improvements—more rapid growth and development, greater vitality at all ages, and longer life. This comparison was carried out on such large numbers of animals that there can be no doubt as to the reliability of these results. It should be emphasized that, as Sherman said, “when superior nutrition increases the length of life this is only one expression of the fact that the life has been lived on a higher level of health and efficiency throughout. In the individual, it means not more years of old age but more years in the prime of life.”¹ Sherman also pointed out in discussing these results that it is of far-reaching significance in its implications for the improvability of man, that those families habituated to the diet with the lower proportion of milk through many generations were able to respond in the same manner as the more fortunate families when they were transferred to the diet with the larger proportion of milk.

The value of milk in improving a diet chosen “in good faith and with the best of intentions” and supposed to fulfill all the needs of those for whom it was provided was clearly demonstrated by the four-year experiment in an institution for poor English boys, reported by Corry Mann in 1926. Three cottages, housing boys from six to eleven years of age, were set apart for the dietary study. One group received the regular diet of the institution, six others received supplementary food, as follows: (1) a pint of milk daily, (2) sugar equivalent in calorie value to the pint of milk, (3) New Zealand butter from grass-fed cows to give the same number of calories as the milk, (4) unfortified margarine equivalent to the butter, (5) edible casein furnishing only 65 extra calories, (6) $\frac{3}{4}$ ounce daily of fresh water cress. The group on the regular diet gained during the four-year period an average per year of 3.85 pounds and 1.84 inches. Extra protein in the form of casein made practically no difference in weight or height. Extra calories in the form of sugar or margarine made no difference in height and increased weight only a very little, the water cress and butter made a better showing, but the milk group gained 6.98 pounds and 2.63 inches. Mann, at the conclusion of this study, said, “It is startling to learn, as we now do, for in-

¹ Sherman, H. C. *Chemistry of Food and Nutrition*, 8th edition, page 669. The Macmillan Co. (1952).

stance, that the addition of one pint of milk a day to a diet which by itself satisfied the appetite of growing boys fed upon it could convert an average annual gain of weight of 3.85 pounds per boy into one of 6.98 pounds, and an annual average increase of height from 1.84 inches to 2.63 inches. This unmistakable betterment in nutrition was proved by trial to be due, not to the relatively small increase in the fuel value of the dietary, nor to the extra protein supplied in the milk, but rather to more specific qualities of milk as a food.”²

This work led the Department of Health for Scotland to undertake a series of extensive studies of the influence of milk consumption on the growth of school children in the years 1927–30, involving more than 12,000 children who were fed milk daily at school as a supplement to their regular fare, and about an equal number not given any supplementary food who served as controls. The results substantiated Mann’s findings, even when only $\frac{3}{4}$ pint of milk daily was furnished each child for four months. The report by Leighton and McKinlay in 1930, of a study of 20,000 children five to twelve years old in Lanarkshire, 10,000 of whom had the milk supplement, concluded with these significant words: “The results, read along with the results of the previous Scottish test, are conclusive on the main issue. They demonstrate that the addition of milk to the diet of children has a striking effect in improving physique and general health and increasing mental alertness. They suggest also that, apart from its own food value, milk enables the other constituents of the ordinary diet to be fully utilized as growth factors.”³

During the last week or two of the test the various head teachers of the schools were asked to submit in writing their general impressions of the effect upon the children. They spoke of “an increase in the bloom of their cheeks and the sleekness of their skins,” and one went so far as to say, “in the playground buoyancy and pugnacity are developing to an alarming extent.”

These accumulating evidences of the many ways in which milk functions in nutrition have served to emphasize its indispensability in

² Mann, H. C. Corry. *Diets for Boys during the School Age*, Preface. Medical Research Council, Special Reports Series, No. 105. His Majesty’s Stationery Office, London (1926).

³ Leighton, G., and McKinlay, P. L. *Milk Consumption and the Growth of School Children*, pages 2 and 3. His Majesty’s Stationery Office, London (1930).

the diet, not only of the child, but also of the adult. No other food can so well serve as the foundation of an adequate diet, because no other reinforces it at so many points. It is for this reason that the term "protective food" is aptly applied to milk.

Energy Value

A quart of whole cow's milk yields 666 calories. For the child a year old it will supply nearly two-thirds of the total calories required per day; for one five years old, two-fifths of the total calories; for a boy or girl ten years old, nearly one-third; and for a city-dwelling man of moderate activity about one-fifth. Drinking a single glass at each meal adds about 500 calories a day above what would be taken were water the only beverage. Thus it can be readily seen that milk, although nothing to chew, is not insignificant as body fuel.

By measure it takes $\frac{5}{8}$ cup to furnish 100 calories. This is equivalent in energy value to $1\frac{1}{3}$ eggs or 2 yolks; to about $2\frac{1}{4}$ ounces of lean round of beef; to 1 medium potato or 1 shredded wheat biscuit.

The energy value of other kinds of milk will be found in Tables II and IV in the Appendix.

Protein

A quart of milk yields more than an ounce of pure protein of the highest quality, not only because of an assortment of essential amino acids whose efficiency in promoting growth is unexcelled, but also because under normal conditions it is the most completely digested and absorbed of all food proteins. From every point of view milk is an economical source of protein. Its protein is produced at less expense than that of meat or eggs. The milk cow has been reported to be more than three times as efficient in transforming the protein of its feed into milk protein as are beef cattle or sheep in the production of protein as meat. It has also been found that the feeding of milk cows is more than twice as economical of energy as the feeding of beef cattle or sheep.

Milk enhances the nutritive value of bread and other cereal proteins by adding those essential amino acids such as lysine and tryptophan in which cereal proteins are relatively poor. Experiments in feeding the lowest amount of protein capable of maintaining nitrogen balance in the adult have shown that less protein is required when

milk is practically the sole source than when meat is so used, and that proteins derived half from bread and half from milk furnish a mixture which is utilized with the same economy as milk alone.

A calorie share or 100-calorie portion of milk carries 2.5 shares of protein, and milk is therefore to be regarded as relatively rich in protein. The extra 1.5 shares are available to make good the lack in some other food.

Mineral Elements

In milk are found all the different kinds of mineral elements needed in nutrition. Milk ash strongly resembles in its composition the ash of the body of the newborn young to be nourished by it. The table below gives the amount of the various mineral elements in 1 quart of cow's milk.

Milk is particularly adapted to offset the total lack of mineral elements in fats and sugars and the serious mineral deficiencies of white flour, hominy, polished rice, and other refined cereal products so widely used in American dietaries. Enriched or restored cereal products have, however, added iron. Even where other sources of the mineral elements are included, such as fruits and vegetables, the need for milk remains, since the calcium of the diet depends more upon this than upon any other food.

MINERAL ELEMENTS IN ONE QUART OF COW'S MILK

	<i>Grams</i>
Calcium	1.152
Magnesium	0.117
Potassium	1.396
Sodium	0.498
Phosphorus	0.908
Chlorine	1.035
Sulfur	0.332
Iron	0.001
Copper	0.0003
Manganese	0.0001
Iodine	Present

The indispensability of milk as a source of calcium for the growing child has already been discussed at length and the desirability of a quart of milk daily to insure the best storage of calcium in the body has been emphasized. Shortage of calcium does not affect growth as quickly as shortage of calories, protein, or some of the

vitamins. It is therefore possible for a child to grow up "calcium poor." Normal development during growth demands a steady increase in the store of body calcium and this cannot be achieved without a dietary program which insures a liberal daily supply. To substitute vegetables for all of the milk would be practically impossible, even if their calcium could be as well utilized, since about 4 pounds of those relatively high in calcium would be required, and no child could eat so much in a day.

While phosphorus is less likely to be deficient in the dietary than calcium, since it is present in a wide variety of food materials, the necessity of a liberal supply makes the contribution of milk significant. When the calcium requirement is met through the use of milk, we have every reason to believe that the phosphorus requirement will also be covered.

Although milk is not as rich in iron as in calcium or phosphorus, the iron present is in a form which can be most completely absorbed and utilized, and in the diet of the young child a quart will furnish about one-tenth of the daily recommended allowance.

Since it has been shown that copper is essential to the utilization of iron and since milk is low in copper, it is desirable that the rest of the iron needed come from whole grains and vegetables, which will also furnish copper, thus aiding in a more efficient use of the iron of the milk.

Vitamins

"The cow and the hen consume relatively large quantities of green stuffs, separate the vitamin values from the roughage, and transmit in their milk and eggs a large share of the vitamin value to their young or to the human consumer in a highly assimilable form and accompanied by proteins, fats, and mineral elements all of which are also in forms of exceptionally high nutritive value or efficacy."⁴

A quart of milk yields about three-fourths as much vitamin A as a cup of unclarified tomato juice or a quart of orange juice or about $\frac{1}{2}$ ounce of carrots or $\frac{2}{3}$ ounce of spinach. From laboratory experiences with diets in which milk furnishes one-fourth of the total calories, an amount corresponding to about a quart a day for each child and a pint for each adult in the average family dietary, it ap-

⁴ Sherman, H. C. *Chemistry of Food and Nutrition*, 4th edition, page 367. The Macmillan Co. (1926).

pears that this much milk yields a large portion of the vitamin A for normal growth and that additions from other foods, such as butter or margarine, eggs, and green and yellow vegetables, may therefore be regarded as an investment for periods of rapid growth in childhood or for special demands such as pregnancy and lactation in the adult, as well as the maintenance of a high resistance of the tissues at all times.

Milk is also fairly rich in thiamine, 1 quart being equivalent to about $1\frac{3}{4}$ cups of orange juice, to 3 cups of tomato juice, to 12 ounces of spinach, or to 18 ounces of cabbage. Since the amount of thiamine required by growing children increases with increasing size, and since the utilization of other foodstuffs has been shown to be promoted by liberal amounts of thiamine, it seems fortunate that in taking as much as a quart of milk for the sake of its protein, calcium, and vitamin A we are also furnishing a considerable portion of the thiamine needed to meet the recommended daily allowance.

Milk is less dependable as a source of ascorbic acid than of any other known vitamin. The amount in fresh raw milk is not very large and varies considerably with the diet of the cow. Pasteurizing milk at 142° to 145° Fahrenheit for one-half hour reduces its ascorbic acid content about 20 per cent. Longer heating or contact with certain metals, especially copper, will destroy more of the vitamin. Standing in a bottle on the doorstep in the sun for a half hour is enough to cause a considerable loss of the vitamin. The contributions to the diet of 1 glass of pasteurized milk are shown in Fig. 111 in comparison with a half cup of evaporated milk and a 1-inch cube of Cheddar cheese.

Milk, having both calcium and phosphorus in liberal quantities, is indispensable for good bone growth, but it needs supplementing with vitamin D. It is rich in riboflavin compared with most vegetables which have been studied, a quart yielding about as much as $1\frac{1}{4}$ pounds of kale or about $2\frac{1}{4}$ pounds of shelled peas. It is also relatively rich as compared with lean beef or eggs, a quart being equivalent in this vitamin to about $1\frac{3}{4}$ pounds of lean beef or to 10 eggs.

Milk owes its importance in the diet to the fine quality of its proteins and their supplementary value for cereal proteins; to the completeness of its assortment of mineral elements and the excellent

proportions in which they occur; to the high content of calcium and phosphorus, which makes milk almost indispensable for good growth of bones and teeth; to the liberal amounts of vitamin A and ribo-

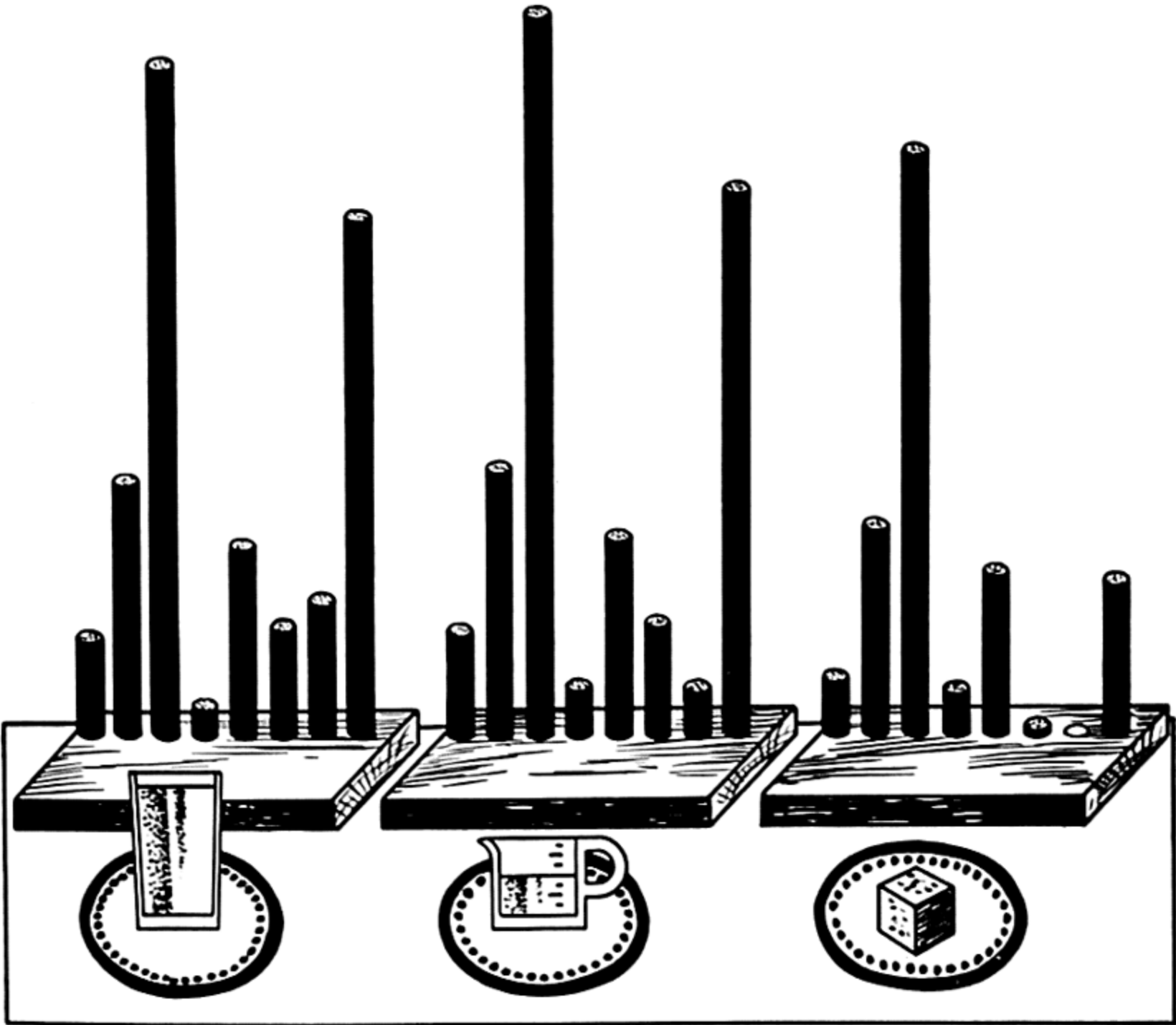


Fig. 111. Contributions to the Diet Made by Pasteurized Milk, Evaporated Milk, and Cheddar Cheese

	Shares in Order on Blocks							
	Cal- ories	Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascor- bic Acid	Ribo- flavin
Milk, past., 1 glass	1.66	4.2	11.5	0.5	3.1	1.8	2.1	8.8
Milk, evap., 1/2 cup	1.74	4.4	12.3	0.7	3.3	1.8	0.7	9.1
Cheese, Cheddar, 1" cube	1.13	3.5	9.9	0.8	2.6	0.2	0	2.4

flavin which make a quart of milk a day in a good mixed diet a practical guarantee against deficiency of either; and to a considerable amount of thiamine. The amount of ascorbic acid is uncertain, so orange or tomato juice, or some other equally good source, should be used. It contains but relatively little of vitamin D, so that more

of this vitamin should always be obtained from other sources or by use of vitamin D milk.

Evaporated milk is widely used because of its convenience and economy, and, in the case of infants, because of its ease of digestion, due to the fine flaky curds formed in the stomach. The investigations of Blunt at the University of Chicago and of Kramer and her associates at the Kansas Agricultural College have shown that the calcium and phosphorus are well absorbed and utilized in fluid milk, raw or pasteurized. Vitamins A and D are not materially altered by the processes employed in the evaporation of milk, and evaporated milk is generally fortified with vitamin D. Thiamine is likely to be reduced by about 25 per cent. Any destruction of ascorbic acid is not a serious matter since it is now customary to give infants and children orange juice or some other supplement for this vitamin regularly.

Evaporated milk is pure cow's milk minus about 60 per cent of its water and is not to be confused with sweetened condensed milk which is preserved by the addition of a large amount of cane sugar.

Powdered milk is made from either whole milk or skim milk. Both are excellent products from the nutritional standpoint and, prepared by modern methods, retain all the food values of the original whole or skim milk, excepting possibly the ascorbic acid. The vitamin A removed in the production of skim milk must be provided by other good sources of this vitamin in the diet. The instant skim milk powder is so easy to mix and has such good flavor that its use is increasingly popular.

Vitamin D milk (either homogenized or cream-line) is a sound public health measure and offers additional protection against rickets for the infant and young child. Antirachitic properties have been successfully imparted to both fresh and evaporated milk by irradiation, by addition of an extract of cod liver oil (oil free), or by feeding irradiated material to the cow. Today most milk is fortified with the direct addition of vitamin D during processing. The vitamin is in the form of a sterile canned concentrate dissolved in a milk carrier. After careful consideration of the experimental evidence, the Council on Foods and Nutrition of the American Medical Association concluded that excellent protection is afforded by milk with 400 International Units of vitamin D per quart. However, even if vitamin D milk is used, the young child is still better protected if given in

addition at least a teaspoonful of cod liver oil or a fish liver oil capsule daily.

Since World War II special attention has been given in many countries to increasing the consumption of milk because of the growing appreciation of the importance of milk in safeguarding the health of infants, children, and expectant and nursing mothers. Since the war the volume of dried and condensed milk in international trade has more than doubled.⁵ The increased consumption of fluid milk in some countries and the great increase in the export of dried and condensed milk has been made possible by using less milk for production of butter. The following tabulation tells an interesting story.

MILK CONSUMPTION AND PROPORTION OF TOTAL MILK USED FOR BUTTER

Country	Milk Consumption ^a (Kg. per Capita per Yr.)		Percentage of Total Milk Used for Butter	
	Prewar	Recent	Prewar	Recent
Denmark	195	221	80	70
Norway	207	301	42	30
Switzerland	307	344	20	13
United Kingdom	152	213	15	5
United States of America	249	289	42	28
Australia	165	201	78	66
New Zealand	168	240	67	67

^a Milk in all forms except butter.

Section 2. CHEESE

Of the cheese manufactured in the United States the major portion is of the Cheddar variety, commonly called "American" cheese. A pound of such cheese contains the casein and fat of a gallon of milk, together with traces of whey retained by the curd. It has about one-fourth of its calories in the form of protein and the other three-fourths in the form of fat. The milk sugar is mostly withdrawn in the whey or changed to lactic acid in the ripening process. The calcium, phosphorus, and iron of the milk are retained in the cheese and also a large part of vitamin A and riboflavin. The contributions

⁵ Food and Agriculture Organization of the United Nations. "Second World Food Survey" (1952).

to the diet made by a 1-inch cube of Cheddar cheese are graphically portrayed in Fig. 111.

Such a concentration of the most important nutritive elements of milk in a food of excellent keeping qualities entitles cheese to a place in the diet which is not always fully appreciated. Its strong flavor precludes its use in many of the ways in which milk is practical and makes it more akin to meat in regard to its place on the menu. As a substitute for meat it gives a much better return in nutritive value for the money expended and is particularly valuable as a source of calcium in the diet of adults who have not acquired the habit of using milk freely. From 3 to 4 ounces of cheese (except cottage cheese) will furnish enough calcium for an average man for one day.

Because of its flavor cheese is often regarded as a condiment and served with other foods merely to add zest to a meal. It should be remembered, however, that cheese is a concentrated food and is properly used in the diet much as meat would be. Because of its texture and its high proportion of fat calories to total calories it is digested best when used with bread or other cereal foods.

A comparison of the contributions to the diet made by 100-calorie portions of six common cheeses will be found in the tabulation given below.

CONTRIBUTIONS OF 100-CALORIE PORTIONS OF COMMON CHEESES EXPRESSED IN SHARES

Kind	Measure	Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascor- bic Acid	Ribo- flavin
Cheddar	Piece 1" × 1" × $\frac{7}{8}$ "	3.1	8.7	0.8	2.2	0.2	(0)*	2.2
Cottage	$\frac{1}{2}$ cup, scant	10.1	4.0	0.8	(0.1)	0.4	0	6.6
Cream	2 tbsp.	1.2	0.7	0.3	(2.5)	(0.0)	(0)	1.2
Parmesan	$\frac{3}{8}$ cup	4.4	11.6	0.3	2.2	0.2	0	3.6
Roquefort	1 $\frac{7}{8}$ tbsp.	2.9	3.4	0.8	2.1	0.2	0	3.2
Swiss	1 slice	3.6	10.0	0.5	2.5	0.0	0	2.2

* The values given in parentheses in this and all other following tabulations are estimated.

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Bread, Flour, and Cereals

Wherever we have agriculture, we have the cultivation of grains. These afford a staple article of diet, which can be placed in reserve for seasons of scarcity, and one whose keeping qualities and ease of marketing make it relatively cheap. For half the people of the world rice is the chief article of diet. For over one billion people in Asia it provides 80 to 90 per cent of the daily calorie intake. Corn is the staple article of the diet of the populations of Romania, Mexico, Venezuela, Guatemala, and of the Negroes and poor whites of the southern United States. In the United States and Great Britain nearly one-third of the calories in the diet are derived from cereals.

Seldom is the intact kernel of any grain used as food by man in any considerable amount. It is not easy to eat dry whole grains. From time immemorial they have been ground, crushed, or otherwise treated to break up or remove the bran coats. With the increase of trade and the shipping and storing of grain foods, there has grown up the practice of removing the germ because it is here that insects love to deposit their eggs, and the result is ruin so far as fitness for human food is concerned. Also, the oil of the germ tends to become altered and spoil the flavor of the cereal.

Since we have come to appreciate the value of thiamine, more attention is being given to the preparation of both bran and germ for human use. Very frequently cereals containing bran are called "whole grain" cereals, when they merely contain more or less bran but not the germ. In case of oatmeal, the greater part of the germ and a considerable part of the bran are to be found in the milled product. White rice (polished) has lost both germ and bran, while brown rice (cured) is free from the husk but retains most of the

bran and germ. Pearl barley and barley flour are devoid of both bran and germ. Corn, either white or yellow, is commonly degerminated and most of the bran removed in the preparation of cornmeal. Whole wheat flour, shredded, puffed, and rolled wheat are practically whole grain, while white flour has neither bran nor germ.

In the United States since 1941, programs for the enrichment of white flour, white bread, cornmeal or grits, macaroni and noodle products, and processed food cereals have been put into effect. In 1953 it was reported that 300,000 kilograms of niacin were used, chiefly in flour, bread, cornmeal, and prepared cereals, along with 35,000 kilograms of thiamine and 20,000 kilograms of riboflavin.

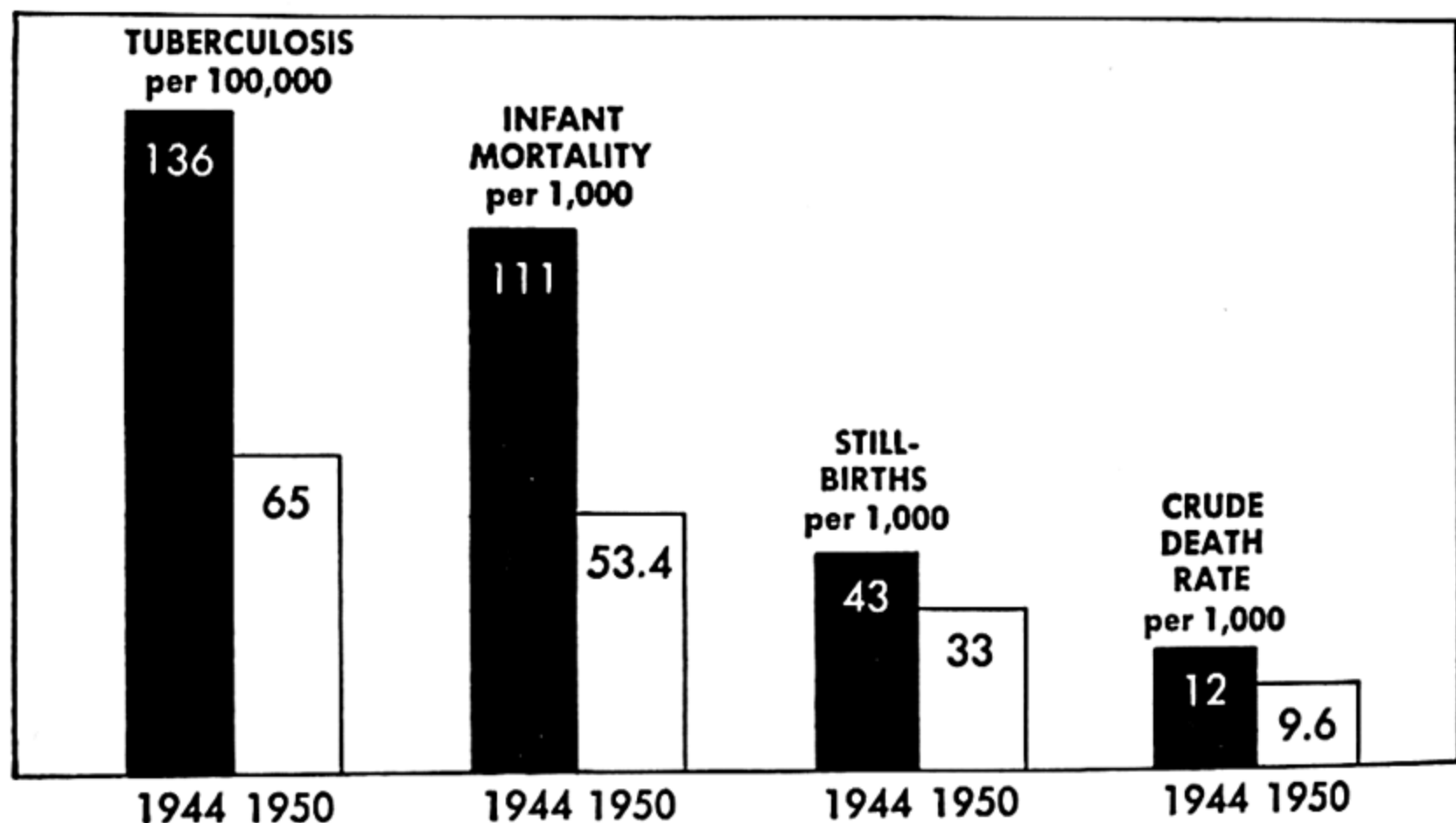
Since 1943, any flour labeled "enriched" must contain per pound 13 to 16.5 milligrams of iron, 2 to 2.5 milligrams of thiamine, 1.2 to 1.5 milligrams of riboflavin, and 16 to 20 milligrams of niacin or niacinamide. Optional with the producer, the flour may also be enriched with calcium to make the content of this element 500 to 625 milligrams per pound and with vitamin D to make the content of this vitamin 250 to 1,000 U. S. P. units per pound. Although enrichment is not compulsory in all states, it has been well supported by industry and it has been estimated that three-fourths or more of the total output of white flour and bread is enriched.

By 1950, 26 states as well as Puerto Rico and Hawaii had enacted legislation requiring enrichment of bread and flour. The practice of flour enrichment has been adopted in Canada, Denmark, and Norway and at the time of this writing is being inaugurated in Chile. It is reported that Guatemala, Costa Rica, Panama, and San Salvador have enacted or are about to enact legislation requiring the enrichment of imported white flour and that it is being considered in Cuba. In the Philippines, an executive order was signed in August 1954 providing for the introduction of rice enrichment in every city and province during 1955 and 1956. That dramatic health benefits from enrichment are possible are graphically presented in Fig. 112 showing the decline in the mortality rates in Newfoundland following the enrichment of flour and the fortification of margarine with vitamin A in 1944.

Energy Value

Since the uncooked cereal foods are all very low in moisture content and have great similarity in chemical composition, they

have much the same energy value, approximating 1,650 calories per pound. The weight of a 100-calorie portion (dry) is close to 1 ounce, although the space occupied by 1 ounce will differ with the coarseness of the material, from 3 tablespoonfuls of whole wheat flour to



(Courtesy of The National Vitamin Foundation, Inc.)

Fig. 112. Decline in Mortality Rates in Newfoundland Coincident with Flour Enrichment (1944–1950)

2½ cups of puffed wheat, or 1 shredded wheat biscuit. When cooked, there will be variation in weight as well as measure, the dry cereal swelling from two to five times its volume, due to the amount of water absorbed.

Protein

From 8 to 12 per cent of the calories in cereal foods are derived from protein. In their analysis of 92 American dietaries in 1917, Sherman and Gillett found that grain products contributed 38 per cent of the total calories and 36 per cent of the protein. In a United States Department of Agriculture study of food consumption by American families during the years 1935–39 it was found that the grain products contributed 27.8 per cent of the calories and 28.7 per cent of the protein. During the years 1947–49 the contributions of these products had dropped to 23.8 per cent of the calories and 22.9 per cent of the protein. For the year 1953 the figures reported were 22.4 per cent of the calories and 21.1 per cent of the protein. It is

generally safe to assume that in grain products one or more shares of protein will accompany a share of energy. Therefore it can be said that cereals carry their quota of protein in the diet.

We have already seen, in the discussion of protein in Chapter 8, that individual cereal proteins differ in their amino acid assortment, but that several kinds of protein are found in one grain, and the proteins of bran and germ tend to supplement those of the endosperm. Laboratory experimentation has shown that the proteins of wheat, oats, maize, rye, and barley are about equally efficient in promoting and supporting growth. None of them is quite equal in value to an equivalent weight of the complete proteins which we find in milk, eggs, or meat, but all of them can be made highly efficient by combination with relatively small amounts of milk.

The proteins of white flour will not support growth as well as those of the whole grain, although they are very efficiently used in the maintenance of the adult. But if bread be made with milk instead of water or if breakfast cereals be eaten with milk, the value of the combination may equal the average protein value of an ordinary mixed diet.

Mineral Elements

While there is much similarity in the energy and protein values of cereal foods, including highly refined flour and white bread, there is great diversity in their yield of mineral elements. Much of this is due to milling, since the outer coats of the grains contain most of the mineral matter. The cereal foods, even when made from the whole grain, are deficient in calcium.

The whole grains carry more than their share of phosphorus, but this may be reduced by milling, so that the highly refined products carry less. When these cereals are combined with milk, the high phosphorus content of the milk more than makes up this deficiency.

The contributions to the diet made by polished rice, rolled oats, and dark farina (whole grain) are shown in Fig. 113, and the data represented by the blocks are given below the figure.

Of the mineral elements lost in the manufacture of white flour, iron is the one that can be least well spared. In the 1948 study previously referred to cereals contributed 16 to 23 per cent of the total iron. The less money available for food, the more dependence there will be on the cereal foods. Therefore, those yielding iron should be

regularly chosen, as they can be made the carriers of this essential element with little or no extra cost. Studies of children's dietaries make it quite evident that no very economical diet for a child can be liberally supplied with iron without the use of cereal foods (in-

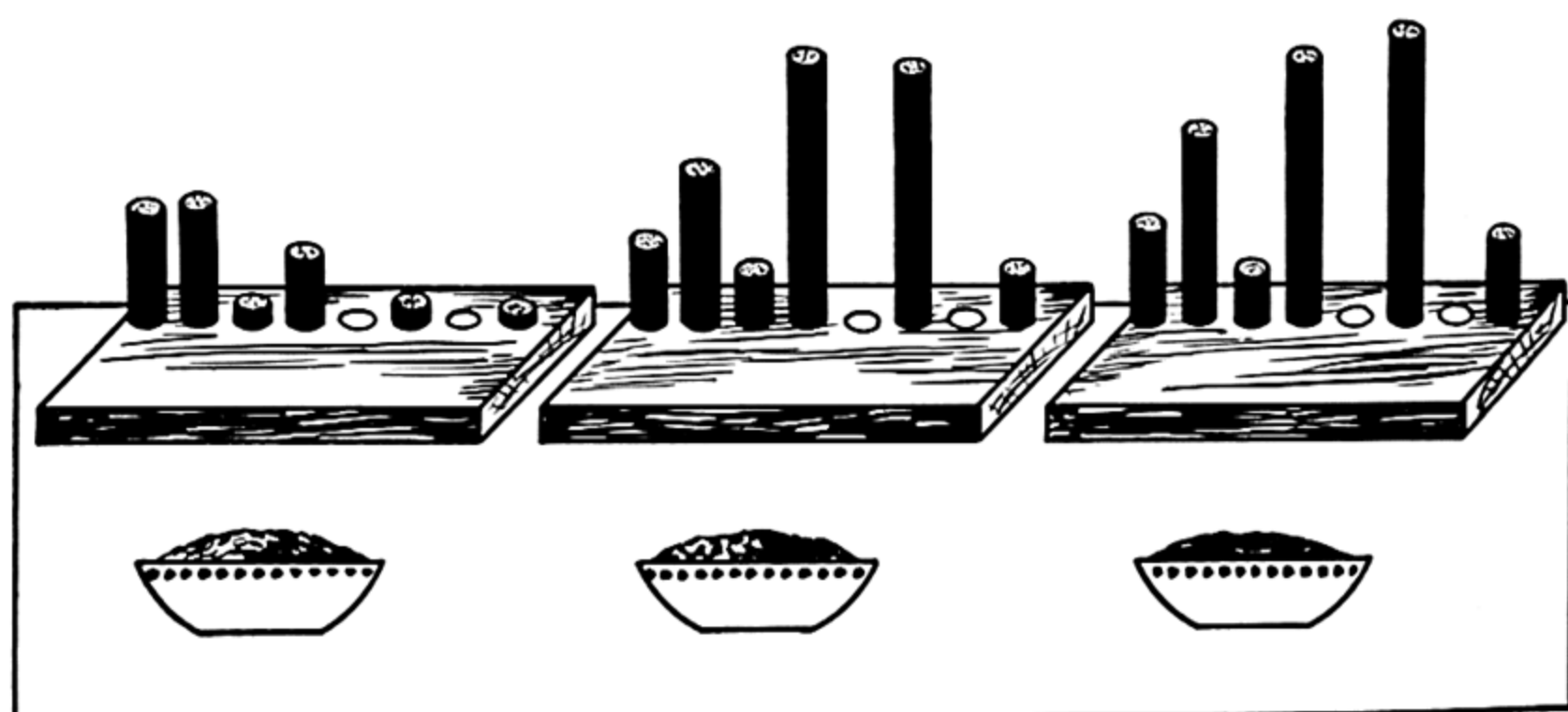


Fig. 113. Contributions to the Diet Made by Cooked Portions of White Rice, Rolled Oats, and Dark Farina (Wheatena)

	Shares in Order on Blocks							
	Cal- ories	Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascor- bic Acid	Ribo- flavin
Rice, white, $\frac{1}{2}$ cup	1.50	1.6	0.4	1.0	0	0.3	0	0.2
Oats, rolled, $\frac{1}{2}$ cup	1.11	2.0	0.6	3.4	0	3.3	0	0.8
Farina, dark (Wheatena), $\frac{1}{2}$ cup	1.31	2.5	0.7	3.4	0	3.8	0	1.2

cluding breadstuffs) which contain it, that is, the whole grain or enriched forms.

The contributions to the diet made by three types of bread are shown in Fig. 114, and the data expressed in shares are given in the table below the figure.

Vitamins

Whole grains, like other seeds, are relatively poor in vitamin A, and whatever amount is present is found chiefly in the germ so commonly removed. They are entirely lacking in ascorbic acid and vitamin D and contain only small amounts of riboflavin. Hence no dependence should be placed on cereals for any of these vitamins.

On the other hand, both germ and bran are excellent sources of thiamine. The germ is about four times as rich in this vitamin as

whole wheat flour. Wheat germ is more appreciated as food for human beings since the general need for generous amounts of thiamine has been shown by laboratory and clinical tests. It may be safely used where the cellulose of bran is objectionable; and it is

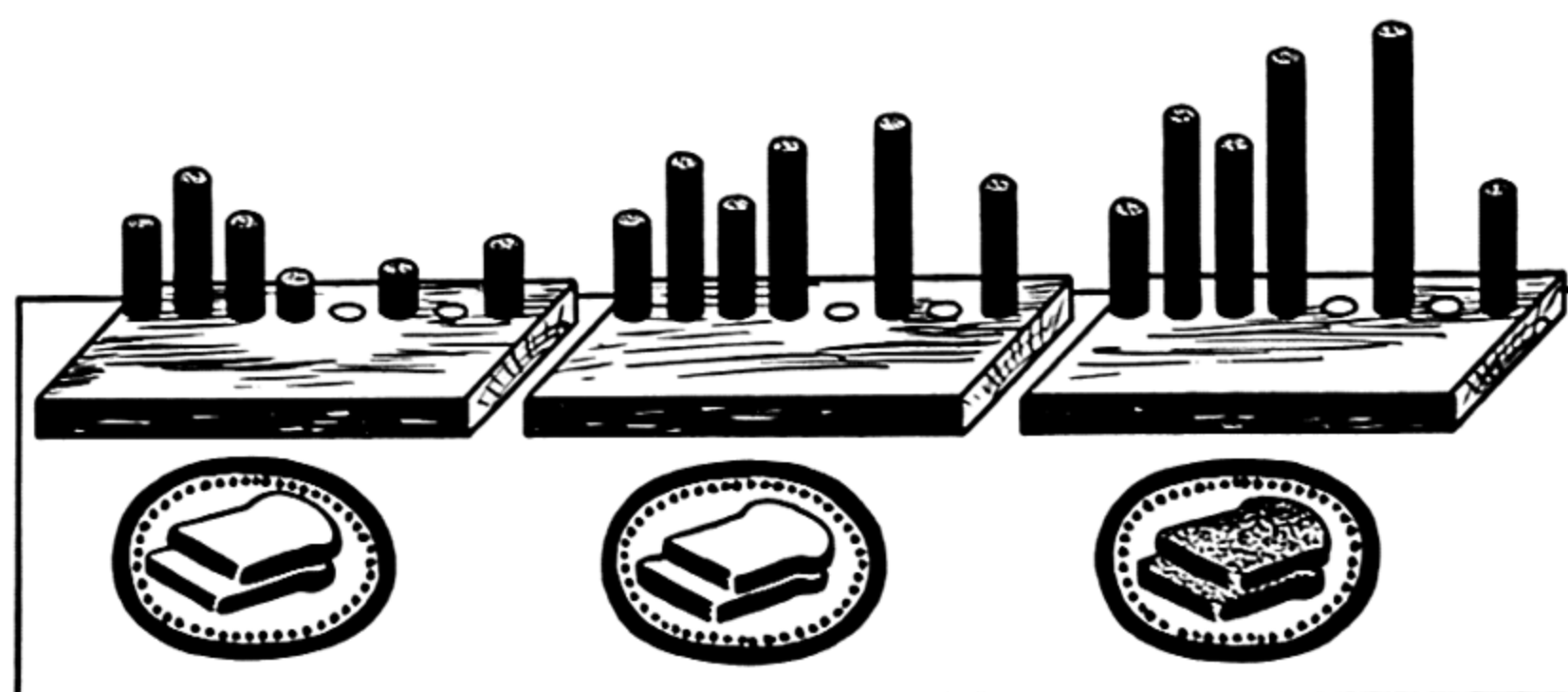


Fig. 114. Contributions to the Diet Made by White Bread, Enriched Bread, and Whole Wheat Bread (Two Slices of Each)

Shares in Order on Blocks

	<i>Cal- ories</i>	<i>Pro- tein</i>	<i>Cal- cium</i>	<i>Iron</i>	<i>Vita- min A</i>	<i>Thia- mine</i>	<i>Ascor- bic Acid</i>	<i>Ribo- flavin</i>
Bread,* white, unenriched	1.20	1.8	1.3	0.6	0	0.5	0	1.0
Bread,* white, enriched	1.26	2.0	1.4	2.2	0	2.4	0	1.6
Bread, whole wheat	1.36	2.6	2.2	3.2	0	3.6	0	1.6

* Made with nonfat milk solids.

helpful where an especially liberal intake of the vitamin is desired without a high calorie intake, as in reducing diets. It may easily be added to the diet of growing children in various ways. Rolls containing 50 per cent of wheat germ were successfully used by Morgan in her study of the effect of added thiamine on the growth of school children (see page 264). Many cereal breakfast foods on the market now contain added wheat germ or vitamins in amounts sufficient to restore those lost in milling and processing. The actual amounts are stated on the package. This is an economical and convenient way to increase the thiamine in the diet. Since milk is rich in riboflavin, in which cereals are low, and whole grains are such an excellent source of thiamine, in which milk is not very rich, we have another

good reason for saying that the best foundation for an economical diet is a combination of milk and whole grain or enriched cereals.

Summary

The cereal foods as a class are important as sources of energy, valuable for their abundance, economy, ease of digestion, and bland flavor. Since they can be eaten freely by all, they are also important as sources of protein although it is not of such quality or quantity as to permit of their being relied upon as the sole source. The whole grain and enriched breads and cereals also make significant contributions of iron, thiamine, and riboflavin to the diet as is pointed out in the following tabulation.

CHIEF CONTRIBUTIONS OF 100-CALORIE PORTIONS OF COMMON CEREALS EXPRESSED IN SHARES

	<i>Pro- tein</i>	<i>Iron</i>	<i>Thia- mine</i>	<i>Ribo- flavin</i>
Bread, white, enriched ^a	1.5	1.6	1.8	1.0
Bread, white, unenriched	1.5	0.5	0.4	0.8
Bread, whole wheat	1.9	2.4	2.6	1.0
Cornmeal, ^b enriched ^a	1.1	2.1	2.4	1.4
Cornmeal, ^b unenriched	1.1	0.8	0.8	0.4
Corn grits ^b (hominy), enriched ^a	1.2	2.1	2.4	1.4
Corn grits ^b (hominy), unenriched	1.2	0.8	0.8	0.2
Flour, rye, light	1.3	1.1	0.8	0.4
Flour, white, enriched ^a	1.4	2.1	2.4	1.4
Flour, white, unenriched	1.4	1.1	0.4	0.2
Flour, whole wheat	2.0	3.2	3.4	1.0
Macaroni, enriched ^a	1.7	2.1	4.8	2.0
Macaroni, unenriched	1.7	1.1	0.4	0.4
Oatmeal	1.8	3.4	3.2	0.8
Rice, brown	1.0	1.6	1.8	0.2
Rice, white, converted	1.0	0.5	1.2	0.2
Rice, white, enriched ^c	1.0	2.1	2.6	0.2
Rice, white, polished	1.0	0.5	0.4	0.2

^a Amounts based on the minimum levels of enrichment specified by the Food, Drug, and Cosmetic Act.

^b Degerminated.

^c With "premix" used in the Philippines.

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Vegetables and Fruits

Advances in the science of nutrition have brought into prominence foods formerly held in too low esteem. As long as our knowledge of nutritive values was limited principally to proteins, fats, and carbohydrates, foods which were not good sources of one or all of these received scant consideration. Energy-bearing foods such as dried seeds of legumes, potatoes, and bananas might be assigned a definite place in the diet, but anything as watery as a tomato seemed a poor choice to one whose main thought was calories, when for the same money twenty times as many calories might be purchased in the form of oatmeal or other cereal food. However, research steadily progressed in regard to nutrients other than calories and protein, as has been shown in the chapters on mineral elements and vitamins. In 1911 the first edition of Sherman's *Chemistry of Food and Nutrition* was published, giving quantitative dietary standards for iron, calcium, and phosphorus, along with the first reliable tables of data on the mineral elements in common food materials. Later work served to emphasize the importance of mere traces in the body of essential mineral elements and of vitamins protective in amounts so small as to demand measurement in millionths of a gram, or micrograms. In consequence, vegetables and fruits, which are the ultimate sources of the vitamins and the chief conveyors of the mineral elements of the soil to the animal body, aside from eggs and milk, assumed a new place in human nutrition, and many people found improved health and vigor through their freer use.

In addition to their value for nutrients indispensable for health and growth, vegetables and fruits are also important for their laxative

properties. The human intestinal tract is so constructed that a certain amount of ballast or roughage is needed to keep the muscles in condition and insure prompt elimination of waste. The fibrous framework of leaves, stems, and even some bulbs, tubers, and roots yields a spongy mass which serves the purpose admirably. Furthermore, thiamine has been found to be such an important factor in the normal muscle tone upon which intestinal activity depends that the laxative property of vegetable fiber is increased by its presence in liberal amounts.

Energy Value

Vegetables and fruits vary so greatly in their energy value that no general statement is applicable to all. Reference must be made to tables giving weight or measure for satisfactory information about individual members of this group. Vegetables may be any part of a plant—leaf, stem, bulb, tuber, root, seed or seed pod, blossom or fruit—and like parts tend to similarity in composition. Some fruits, flowers, leaves, and stems, such as tomato, cauliflower, lettuce, cabbage, asparagus, and celery, are practically negligible so far as calories are concerned. Fleshy roots, bulbs, and tubers, being storage parts of the plant, contain energy-yielding carbohydrates either as starch, as in the white potato; or sugar, as in the carrot; or both, as in the sweet potato. From 3 to 8 ounces of any such vegetable will yield 100 calories. Seeds are higher in energy value than other storage parts and when mature and dry resemble the cereal foods, having a fuel value of about 100 calories per ounce.

Among fresh fruits there is also much variability, but many common ones resemble the underground vegetables. It takes almost the same weight of banana as of white potato to yield 100 calories, about the same of apple as of onion, and nearly the same of grapefruit as of carrots.

With the exception of dried fruits and legumes, which per pound yield nearly as many calories as the cereals, we must regard our common fruits and vegetables as contributing only moderately to the energy value of the diet, although when used freely, as is the case with potatoes, they may have more significance as sources of calories. The contributions to the diet of medium-sized portions of three common fruits, the grapefruit, banana, and apple, are shown in Fig. 115.

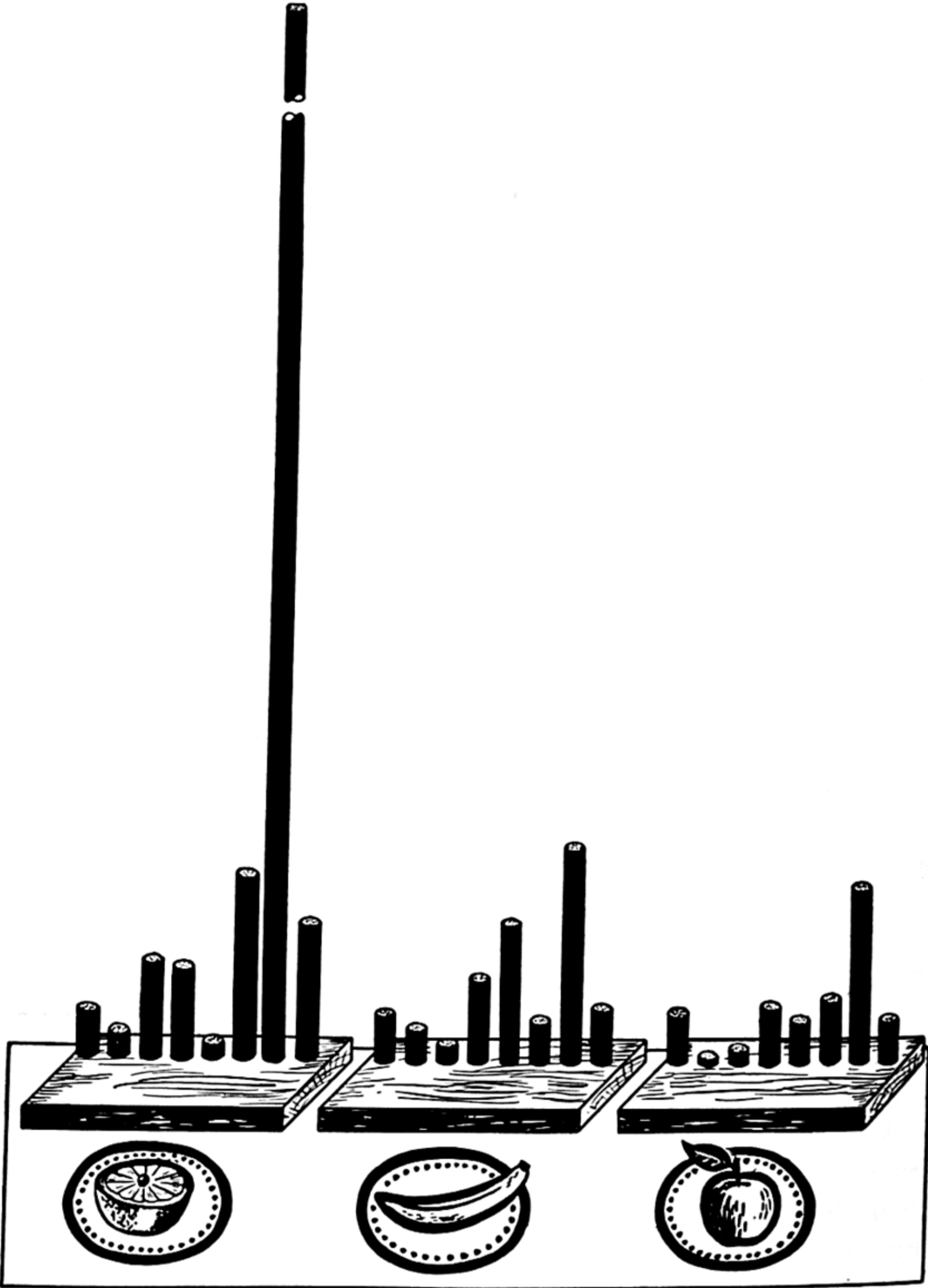


Fig. 115. Contributions to the Diet Made by Grapefruit, Banana, and Apple
Shares in Order on Blocks

	Cal- ories	Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascor- bic Acid	Ribo- flavin
Grapefruit, ½ large	1.00	0.6	2.2	2.1	0.3	4.0	42.7	3.0
Banana, 1 medium	1.00	0.7	0.4	1.8	3.1	1.0	4.7	1.2
Apple, 1 large	1.00	0.2	0.4	1.3	1.0	1.4	3.8	1.0

Protein

Fresh vegetables and fruits are not large contributors to the total protein of the diet. Fruits commonly furnish only half as many shares of protein as of calories; root vegetables usually yield a protein share for every calorie share but have little surplus to make good the protein deficiencies in other foods. In this respect they resemble the cereals. Green vegetables are, in proportion to their calories, surprisingly rich in protein, a 100-calorie portion of collards, escarole, or spinach yielding as many protein shares as one of eggs or smoked ham and a 100-calorie portion of peas as much protein as one of cheese. But in consequence of the fact that one would be likely to eat four or five times as many calories of cheese or egg as of spinach, the total amount of the protein contributed to the diet by green vegetables is very small. The dried legumes have nearly the same proportion of protein to total calories as the green vegetables but are practically more important sources because of the larger number of calories consumed. Differences in the quality of the proteins of vegetables and fruits are discussed in Chapter 8.

Mineral Elements

As sources of mineral elements vegetables are of great importance. Along with those elements needed in relatively large amounts, such as calcium, phosphorus, and iron, we receive in these foods a number of others, such as iodine and copper, which although present in minute quantities are of real significance, as has already been pointed out in Chapters 9, 10, and 11.

Vegetables and fruits are not so rich in calcium that they may be depended upon, in the quantities ordinarily eaten, to furnish sufficient amounts of this element. Leaf and stem vegetables are generally richer in this element than other vegetables or fruits, but turnips and carrots among root vegetables, oranges and strawberries among fruits yield enough to teach us that it is worth while to learn as much as possible about individual foods and not to trust entirely to arbitrary divisions based on botanical classification. Also it is necessary to take account of losses incurred in cooking and to keep in mind that the calcium of some of the leafy green vegetables is not available due to the presence of oxalic acid (see Tables II and IV in Appendix).

Heat alone does not affect the mineral content but when a food is cooked in water, a considerable portion of the mineral salts may dissolve in the water. To reduce these losses to a minimum the smallest amounts of water possible should be used and the cooking water should be saved for use in soups, gravies, vegetable juice cocktails, and other appropriate ways. This procedure should be observed whether the food cooked is fresh, canned, dehydrated, or quick-frozen.

As sources of iron, the green vegetables are extremely important foods. They not only yield needed iron, but provide favorable conditions for its absorption from the digestive tract and for its use in building hemoglobin. Some fresh fruits contribute more than three shares of iron per 100 calories; for example, blueberries, blackberries, raspberries, peaches, cantaloupe, guavas, loganberries, and strawberries. Strictly speaking, the tomato, which is really a fruit, should also be included. Among the dried fruits, prunes, raisins, and figs have approximately three or more shares per 100 calories while apricots have five shares.

Contributions to the diet made by three common vegetables, broccoli, carrots, and peas, are shown graphically in shares in Fig. 116.

Vitamins

One of the best reasons for including vegetables and fruits in the diet is to insure a liberal supply of vitamins. Knowledge of the vitamin content of raw foods of this class and of the changes brought about by storing, cooking, canning, drying, quick-freezing, etc. is therefore necessary for the intelligent planning of dietaries. Cooking may cause considerable loss of some of the vitamins, especially of thiamine and ascorbic acid. In general, the shorter the time of cooking the smaller is the loss. One of the advantages of quick-frozen foods is that cooking time is reduced, quick-frozen vegetables requiring only one-half to two-thirds as much time as the fresh vegetables. Cooking without defrosting has been found to reduce vitamin losses. The freezing process itself brings about little, if any, loss of vitamins. The blanching required before freezing is probably responsible for the major losses occurring. It has been found that minimum loss occurs when blanching time is made as short as possible. In general, it is true that canning of foods causes no greater loss of vitamin values than the usual home cooking processes. It has been reported that

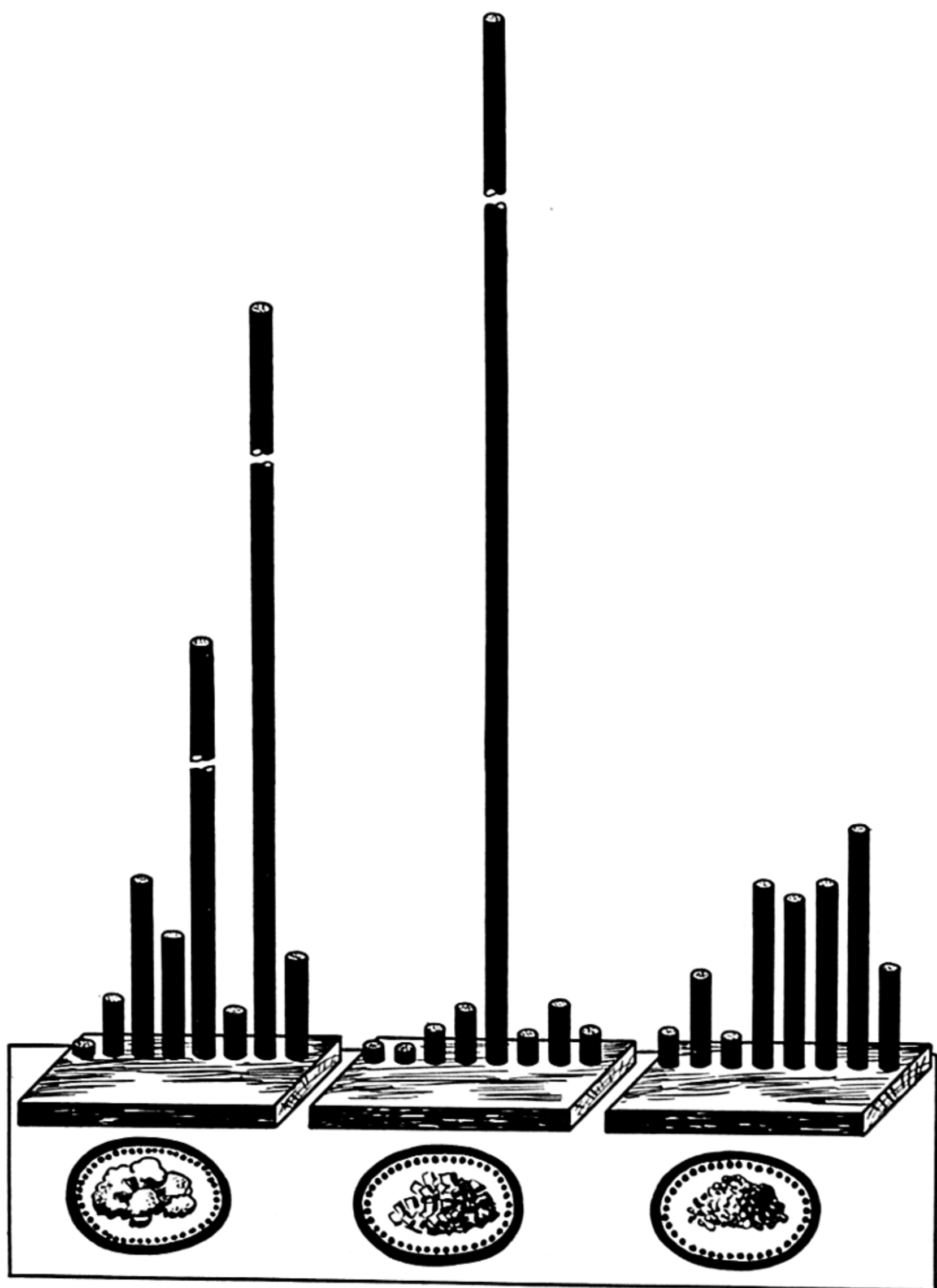


Fig. 116. Contributions to the Diet Made by Cooked Broccoli, Carrots, and Peas

Shares in Order on Blocks

	Cal- ories	Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascor- bic Acid	Ribo- flavin
Broccoli, $\frac{1}{2}$ cup	0.22	1.3	3.9	2.7	16.4	1.0	23.7	2.2
Carrots, $\frac{1}{2}$ cup	0.22	0.2	0.8	1.2	58.1	0.7	1.3	0.7
Peas, $\frac{1}{2}$ cup	0.56	1.9	0.7	4.0	3.7	4.0	5.2	2.2

exclusion of light during cooking conserves riboflavin. Dehydrating fruits and vegetables causes a considerable loss of the vitamins. It is of interest to note that the commercial practice of treating some fruits with sulfur dioxide to prevent darkening during the drying process tends to conserve some of the vitamins. Altogether it seems to be safe to say that, with a few exceptions, the final vitamin values of cooked fruits and vegetables are much the same whether we start with the fresh, canned, or quick-frozen food. Tables II and IV in the Appendix give the yields of most of the common foods.

The richest plant sources of vitamin A are dark green leaves such as spinach, kale, turnip and beet tops, and mustard greens. These can be used interchangeably in the diet. Other green vegetables such as green peas and green string beans make significant contributions although they are not as rich. Bleached leaves, such as the inner leaves of cabbage and head lettuce, have much less than similar leaves when green. Seeds, roots, and tubers generally contain little vitamin A, but the yellow root vegetables like carrots and sweet potatoes are excellent sources.

Thiamine is present in a great many fruits and vegetables. Few vegetables are weight for weight as rich as whole grain or enriched cereals. Peas and beans, both fresh and dried, are a good source of thiamine. In plants thiamine seems to be concentrated in the seeds and not in the leaves, quite the reverse of what is true for vitamin A and ascorbic acid.

Ascorbic acid is obtained almost exclusively from vegetables and fruits, and is so irregularly distributed and so easily destroyed that one must know definitely whether the vitamin occurs in the food material in question and also in each instance the effect of storing, canning, cooking, freezing, or drying. Cabbage is an excellent antiscorbutic when raw but loses much of its value in the process of cooking; tomatoes on the other hand lose but little in the short time required for cooking, and canned tomatoes or juice may be considered a staple antiscorbutic.

The citrus fruits, especially oranges and grapefruit, not only have a relatively high content of ascorbic acid in the fresh state, but retain their antiscorbutic property when concentrated. Lime juice is about half as rich as lemon juice, but although both are good sources they are used in comparatively small amounts. See Chapter 14 for a fuller discussion of the fruits and vegetables as sources of ascorbic acid.

Green vegetables eaten raw vary greatly in their antiscorbutic values. For example, weight for weight, raw green peppers furnish more than ten times as much as escarole. In general, vegetables should be cooked as quickly as possible to conserve ascorbic acid, time being a factor as well as temperature.

Certain root vegetables such as rutabagas and turnips rank high as sources of ascorbic acid if eaten raw. The juice of the uncooked yellow turnip has been satisfactorily used as an antiscorbutic for children when no other source was available.

Mature seeds have little or no ascorbic acid but sprouted seeds are an important source in some parts of the world.

Riboflavin is formed in the growth of the green plant. Seeds, roots, and tubers are relatively poor in this vitamin. Spinach is per calorie share about twenty-five times as rich as potatoes and about three times as rich as cauliflower. Fruits resemble the roots and tubers; even the tomato, so rich in vitamin A and ascorbic acid, is not correspondingly rich in riboflavin.

Summary

Vegetables and fruits vary greatly in energy value. Only the dried seeds of legumes and sweet dried fruits approximate cereals in calories per pound. The relative energy value of the others depends chiefly on the amount of starch or sugar present. Green leaves and stems have little fuel value.

With the exception of dried legumes, few fruits or vegetables are used in quantities which make their protein content significant for the diet as a whole. The quality of the legume proteins although not of the best is such as to provide excellent supplementation and some legumes, soybeans and peas for example, have proteins adequate for growth.

As sources of the many kinds of mineral elements required by the body, vegetables deserve a high place in the diet. In general, fruits are not as rich. Green vegetables are especially valuable as sources of iron and also provide copper, which is essential for the utilization of iron in building hemoglobin. The mineral elements present in fruits are usually of such character as to help greatly in maintaining the normal neutrality of the blood.

As sources of vitamins, vegetables and fruits are of the greatest value. Dark green leaves are, as a rule, rich in vitamin A, thiamine, and riboflavin. Fruits and vegetables which are eaten raw usually

contribute significant amounts of ascorbic acid, but the citrus fruits and tomato juice, which can be eaten regularly in considerable quantities, are the best guarantees of adequate daily amounts of this vitamin. They lose little in cooking, freezing, or canning; many vegetables and other fruits lose much if not all of their ascorbic acid content. Thiamine is quite irregularly distributed in fruits and vegetables; they should therefore be selected with care to insure a liberal intake. Riboflavin is also variable, and while green leaves are good sources, they should be supplemented by other sources, as milk, eggs, liver, kidney, or other meat.

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Meat, Fish, Poultry, Eggs, and Nuts

Among the food groups so far considered, none but milk can be designated an outstanding source of protein. Cereals, legumes, and many vegetables have fair amounts of protein but as already pointed out, none of them is quite equal in value to milk, eggs, or meat. A quart of milk in the diet of the young child will amply safeguard the diet as to protein of good quality, but as the child grows older there will be need of other sources of protein.

Section 1. MEAT, FISH, AND POULTRY

According to the study of American family dietaries by the United States Department of Agriculture in 1942, an average of 23 per cent of the food money was spent on meat, poultry, and fish with a return of 10 per cent of the total calories. Is the expenditure of so much money for meat wise? Does it help to guarantee to the American people adequate diets? The only way to answer these questions is to study carefully the nutritive value of the principal flesh foods. In connection with the prevailing market meats, beef, veal, mutton, lamb, and pork, we may also discuss poultry, game, fish, and shellfish, since nutritionally they have the same characteristics. For the most part, Americans eat muscle tissue to the exclusion of other parts of the animal. Oysters and sardines are the only animal foods of any considerable importance in which the whole body is consumed. This is in marked contrast to the habit of carnivorous animals and of

people living chiefly on animal food, none of whom let any part go to waste.

All kinds of flesh foods contain protein and usually fat; the fat varies greatly in amount with the species of animal and also in case of the larger creatures with the cut. The amount of fat chiefly determines the proportions of other substances, the fat-free flesh being quite uniform in composition.

The amount of any mineral element in meat or fish is more or less proportional to the amount of protein present rather than to the total calories. Lean meats are therefore richer in mineral elements than fat meats, and the higher the percentage of fat, the fewer shares of any mineral element per hundred calories. Meats, poultry, and fish (with the exception of canned salmon) resemble the cereal grains in being deficient in calcium and rich in phosphorus.

The proteins of meats of all kinds are much alike in furnishing a good assortment of essential amino acids, and hence capable of supporting growth, though in no way superior to milk and egg proteins. Like the latter they supplement the proteins of the cereal grains but are not superior to either for this purpose. Quantitatively, lean meat is conspicuous for its high yield of protein, but any increase in fatness quickly changes the proportion of protein to total calories.

According to Sherman, the iron in meat of a given sort is closely proportional to the protein content, and we may expect that the iron content will be high or low in a given piece of meat according as the protein content is high or low. Internal organs, such as the heart, brain, liver, and kidney, are much richer in iron than muscle tissue. Strictly lean meats and eggs are much alike in their contributions of iron to the diet but the meats are poor sources of calcium.

As sources of vitamins, it is necessary to consider separately muscle meats and glandular organs. The former have very little vitamin A or ascorbic acid but are good sources of riboflavin. Most muscle meats are about the equivalent, weight for weight, of eggs as sources of thiamine, with the exception of pork which is outstanding in this vitamin, having eight times as much as whole eggs. Liver is somewhat richer than kidney in riboflavin. Weight for weight, liver and kidney are seven to nine times as rich in riboflavin as whole egg. As a source of vitamin A, liver, the storage organ in the animal body, is spectacularly rich. The small amount of ascorbic acid found in glandular organs is mostly destroyed in cooking.

From the foregoing it is evident that, aside from total calories, the most significant contributions of meat to the average dietary are protein, iron, and riboflavin, and in the case of pork, thiamine. But it should be borne in mind that the amount of protein yielded by a lamb chop can be obtained from $2\frac{1}{2}$ eggs equally well, or $2\frac{1}{2}$ ounces of cheese, or 1 pint of milk, at much less cost and that riboflavin will be furnished at the same time. The second most important contribution of meat is iron, but again, it has no monopoly of this important element; $\frac{2}{3}$ cup of cooked spinach or 2 cups of string beans or 2 egg yolks or 4 slices of whole wheat bread furnish quite as much as a lamb chop, and at less cost.

The chief advantages of meat seem to be its palatability, ease of preparation for the table, and ease of digestion. For these reasons, some meat in the dietary is very acceptable.

The contributions to the diet made by 2 eggs, 4 ounces of lean beef, and 4 ounces of salmon steak are compared in Fig. 117.

Liver and kidney are very different in their nutritive values from the muscle tissue so generally preferred by Americans. They make outstanding contributions of vitamin A and riboflavin and furnish significant amounts of thiamine and ascorbic acid. In contrast, the only vitamin for which muscle meat is at all noteworthy is riboflavin.

Liver is also abundantly supplied with copper, essential to iron utilization, and in studies in which animals have been made anemic by bleeding, liver has proved especially effective in iron regeneration.

The use of small amounts of liver in the diet of young children may be regarded as a distinct advance over the use of ordinary muscle meats. There seems to be little reason, however, to think liver superior to egg yolk for this purpose. Rose and Borgeson¹ added to the diet of nursery school children, who had been observed on a regime without any egg for two and a half years, enough liver to furnish the same amount of iron as an egg a day, and compared them with a group, matching them in age and living conditions, who had been continued on the same type of diet plus an egg daily. Tests of the hemoglobin of the blood and of the number of red cells

¹ Rose, M. S., and Borgeson, G. M. *Child Nutrition on a Low-Priced Diet with Special Reference to the Supplementary Value of an Egg a Day, the Effect of Adding Orange Juice and of Replacing Egg by Liver*. Child Development Monographs, No. 17, page 70. Bureau of Publications, Teachers College, Columbia University (1935).

showed practically no difference in the former and if anything a slight advantage of the egg over the liver in the latter. It would seem that liver and egg can be used interchangeably in the ordinary mixed diet of normal children.

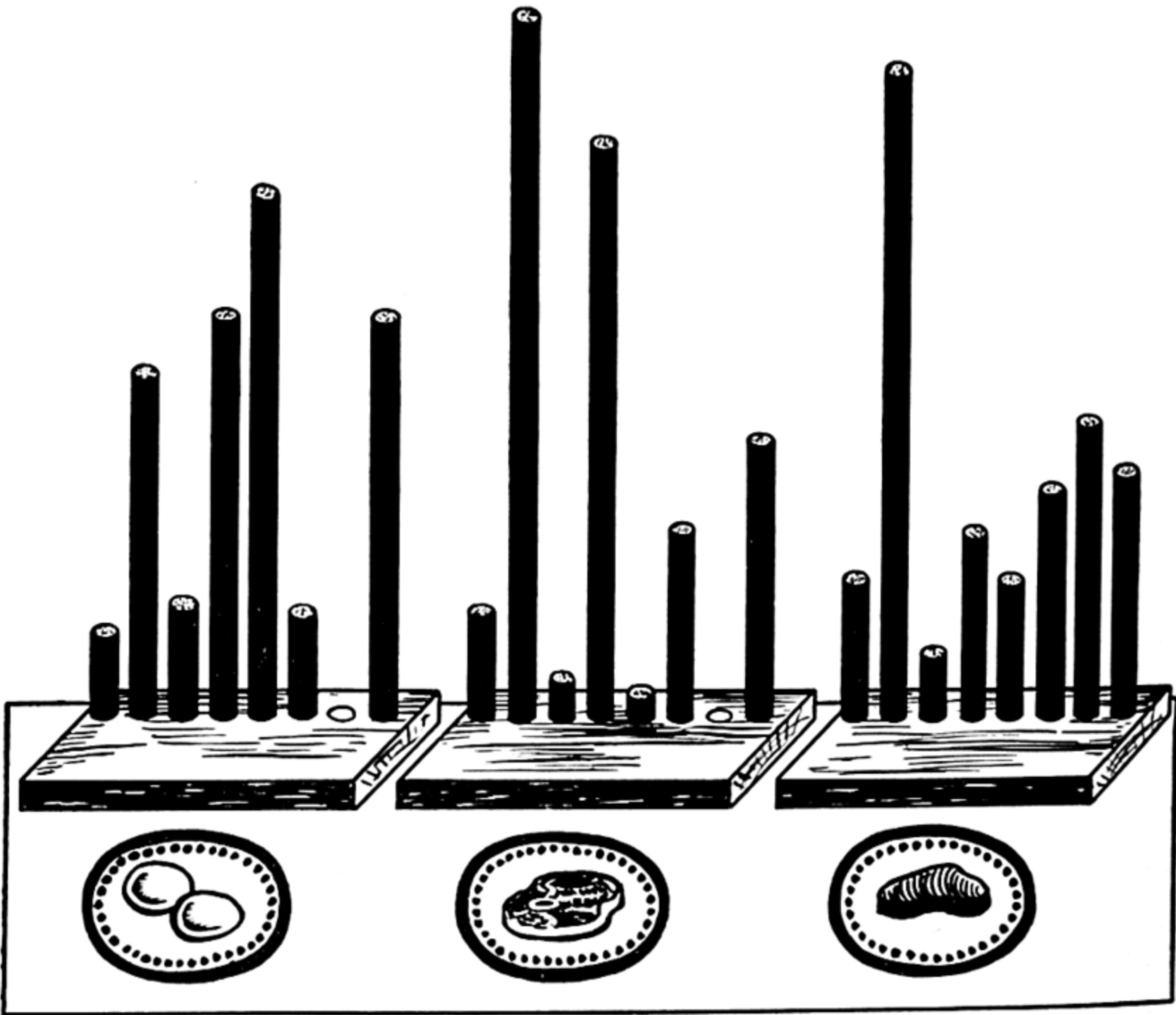


Fig. 117. Contributions to the Diet Made by Eggs, Beef, and Fresh Salmon Steak

	Shares in Order on Blocks							
	Cal- ories	Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascor- bic Acid	Ribo- flavin
Eggs, two	1.50	5.9	2.0	6.8	9.0	1.8	0	6.9
Beef, 4 oz.	1.84	12.0	0.8	9.6	0.4	3.2	0	4.8
Salmon steak, 4 oz.	2.52	11.2	1.2	3.2	2.4	4.0	5.2	4.4

Section 2. EGGS

In making a selection from available sources of protein it is wise to pay attention to other growth-promoting substances which may be secured incidental to the protein. From this point of view, the egg

would be a good choice, and especially the yolk, which is rich in all substances necessary for growth, except calcium and ascorbic acid. In fact, a small amount of egg yolk may profitably be included in the diet of both breast-fed and artificially fed babies as early as the third or fourth month, entirely for the sake of other nutritive factors than protein. By the time a child is one year old, a whole egg may become a regular part of the daily diet.

The chief protein of the egg yolk (ovovitellin) resembles casein of milk in its amino acid content and so does that of the white (ovalbumin). Both are therefore complete proteins independently capable of supporting growth and valuable in bringing to full efficiency proteins of lower value such as the cereal proteins. Next to milk, eggs are the most important protein-bearing food in the diet of the growing child.

The mineral elements of the egg are mainly found in the yolk, which carries more calcium and five times as much iron as needed to balance its own calories. The iron in egg yolk compares very favorably in quantity with that in other foods which may be considered significant sources of iron.

The white of the egg is a rich source of riboflavin but contains no thiamine. The yolk is rich in vitamin A, is a good source of thiamine and riboflavin, but has no ascorbic acid. One whole egg has about the same amount of vitamin A as 1 cup of milk. It has as much thiamine as $\frac{3}{8}$ cup of milk and as much riboflavin as in $\frac{1}{3}$ cup of milk. The amount of vitamin D in egg yolk is small compared to that in cod liver oil, 18 egg yolks having about the same amount as 1 teaspoon of cod liver oil. Eggs cannot be regarded as a substitute for milk, but may be advantageously used in addition to it. They admirably reinforce milk as to iron.

Section 3. NUTS

Nuts are often regarded as a mere adjunct to the dietary to be nibbled between courses at dinner, to add interest to afternoon tea, or to be eaten between meals for pure amusement. Thus used they may prove disturbing to digestion or furnish calories in excess of body needs, for they contain chiefly protein and fat and digest rather slowly and their fuel value is very high. About half an ounce of

almost any one of our common nuts is sufficient to yield 80 to 100 calories. Three Brazil nuts, a dozen medium-sized pecans, or about twenty peanut kernels furnish 100 calories. Chestnuts are the only notable exception to this concentration of energy, about three times as much by weight being required to get 100 calories from them as from other common nuts.

The proteins of nuts of various kinds, including almonds, coconuts, peanuts, and pecans, have been found to be adequate for growth, and chemical analyses of individual proteins from some of these have shown an amino acid assortment rather similar to that of meat and soybeans. Peanut flour, made from the press cake left after the extraction of the peanut oil, has been found an excellent supplement to the proteins of wheat, a bread made with 75 per cent wheat flour and 25 per cent peanut flour giving a mixture in which the protein was adequate for the normal growth of white rats.

In nuts as ordinarily eaten, the proportion of protein to total calories is generally too low to expect them to contribute very significant quantities of protein to the diet.

As sources of mineral elements, nuts as a class are not of much importance because here, again, the amount of mineral element per energy share is usually less than one. In general, they are a better source of iron than of calcium, the cashew nut being exceptionally high in iron. Among nuts for which we have analyses, almonds and filberts are outstanding in regard to calcium.

Nuts are poor in vitamin A and the oil pressed from them is practically devoid of it. They resemble the cereal grains as sources of thiamine and ascorbic acid, having a considerable supply of thiamine and practically no ascorbic acid. Of the nuts which have been investigated as to riboflavin potency, almonds have about two shares per share of calories; others contribute considerably less.

Because of their dense nature, nuts are not easily penetrated by the digestive juices. To be readily digested they need therefore to be very thoroughly masticated or else finely ground. Peanut or other nut butters are excellent examples of nuts prepared in a way to increase ease of digestion. Nuts should also be combined with foods low in fat if they are to be consumed in any considerable quantity; otherwise their high fat content makes the total fat of the diet too great for speedy gastric digestion. When these considerations are given due weight, nuts are an excellent kind of food and may well be used more freely than is generally the practice.

Summary

Meat, fish, poultry, eggs, and nuts are grouped together because they possess the common property of contributing to the diet proteins of the highest quality in amounts which are absolutely as well as relatively significant.

Eggs in addition to protein are rich in vitamin A, thiamine, and riboflavin and also in iron and phosphorus; they therefore serve like milk to reinforce the diet at several points and deserve special emphasis for their growth-promoting properties. Meat in the American diet means chiefly muscle tissue, which unless very fat is high in protein, phosphorus, and iron, and fairly rich in riboflavin, but very deficient in calcium, in vitamin A, ascorbic acid, and does not contain a significant amount of thiamine, excepting in the case of pork.

Liver and kidney are relatively rich in vitamin A, thiamine, and riboflavin but, like other meats, need to be supplemented by milk or cheese for calcium, and by some fruit or vegetable for ascorbic acid.

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Fats, and Sugars, and Other Sweets

Fats and sugars are primarily sources of energy. As body fuel, fats and sugars are interchangeable, calorie for calorie, under ordinary living conditions. Sugar required in the body can be derived from starches, dextrins, and proteins. Certain indispensable fatty acids are easily obtained in the minute amounts needed from the fats used in an ordinary mixed diet so that no special provision has to be made for procuring them. In daily life, fats and sugars are not interchangeable. The diabetic, deprived of sugar, finds small consolation in a generous allowance of fat. Sugar does not altogether make good the feeling of emptiness on a ration devoid of fat. Even though they are interchangeable sources of calories, both are needed to make a satisfactory diet for most human beings.

Section 1. FATS

Fat is the most concentrated form of body fuel. It takes only $\frac{1}{2}$ ounce (1 tablespoon) of fat to yield 100 calories, and a person could get a whole day's fuel from $\frac{3}{4}$ pound of fat if he were able to eat it. On the other hand, people of the Orient, who because of poverty live largely upon rice and in consequence have to eat a great quantity of food to secure sufficient fuel for their daily activities, develop distended abdomens. It would take 5 pounds of cooked rice to give the same number of calories as $\frac{3}{4}$ pound of fat or oil. The latter would not fill a pint measure; the former would measure about $3\frac{1}{2}$ quarts.

When for any reason a person is put on a milk diet for a considerable time, it is customary to add something to the milk to increase its concentration (such as more cream and more milk sugar), if any attempt is made to keep the energy intake up to what it would be on a full mixed diet. A man's energy requirement can be met by 4 to 5 quarts of milk per day if he is not doing extremely heavy manual labor, but it would be more satisfactory to substitute for 1 quart of the milk half a loaf of bread, which is comparatively dry, and for another quart, 3 ounces (6 tablespoons) of butter, thus reducing the volume with little change in energy value. For growing boys and girls and for men engaged in strenuous physical exercise, fat is almost essential if they are to get enough total calories.

Furthermore, fat gives the diet "staying" qualities. Other things being equal, one feels hungry sooner after a meal with little fat than after one in which it is liberally supplied. This is because fat leaves the stomach more slowly than proteins or carbohydrates and retards the digestion of either of these when used in combination with them. A mixture of fat and protein digests more slowly than one of fat and carbohydrate. Probably part of the popularity of meat is due to the fact that it is a protein-fat mixture in which the fat contributes very definitely to the feeling of satisfaction after the meal.

Too much fat may result in undue slowness of digestion and digestive upsets. How the fat is used in cooking also has much to do with its ease of digestion. Butter spread cold upon bread will digest more easily than butter fried into potatoes or incorporated in a sweet cake. The texture produced in the potatoes will not be favorable to rapid digestion and the fat will also exert its retarding influence. For a young child, the summation of effect is too great a risk. The sugar of cake is likewise a complicating factor. The same amount of sugar eaten alone would be quickly absorbed, whereas the mixture is likely to be disposed of more slowly and not always harmlessly.

Used with proper discretion, all of our common food fats, both animal and vegetable, digest easily and almost completely. As sources of energy the different food fats are practically interchangeable. Some prefer olive oil, some pork fat; others revel in seal oil. The ancient Romans prized vegetable oil for food and butter for cosmetics.

For a long time it was not known that there were fat-soluble

vitamins, but now we have to consider fats also as possible sources of these dietary essentials. As Sherman pointed out, "A surplus of vitamin A is not simply a reserve asset to be used at some future time but also actively increases the vigor and ability of the body to resist disease." Careful consideration should be given to the bearing which this has upon the choice of fat. If a quart of whole milk is consumed daily, it will furnish about as much vitamin A as 2 ounces of commercial butter, and if in addition to the milk, green vegetables are consumed in liberal amounts, there need be no fear of a deficiency of vitamin A. When milk is less freely used the habit of eating butter or fortified margarine is a safeguard of real importance. Vegetable oils, whether fluid or hardened by hydrogenation, are lacking in

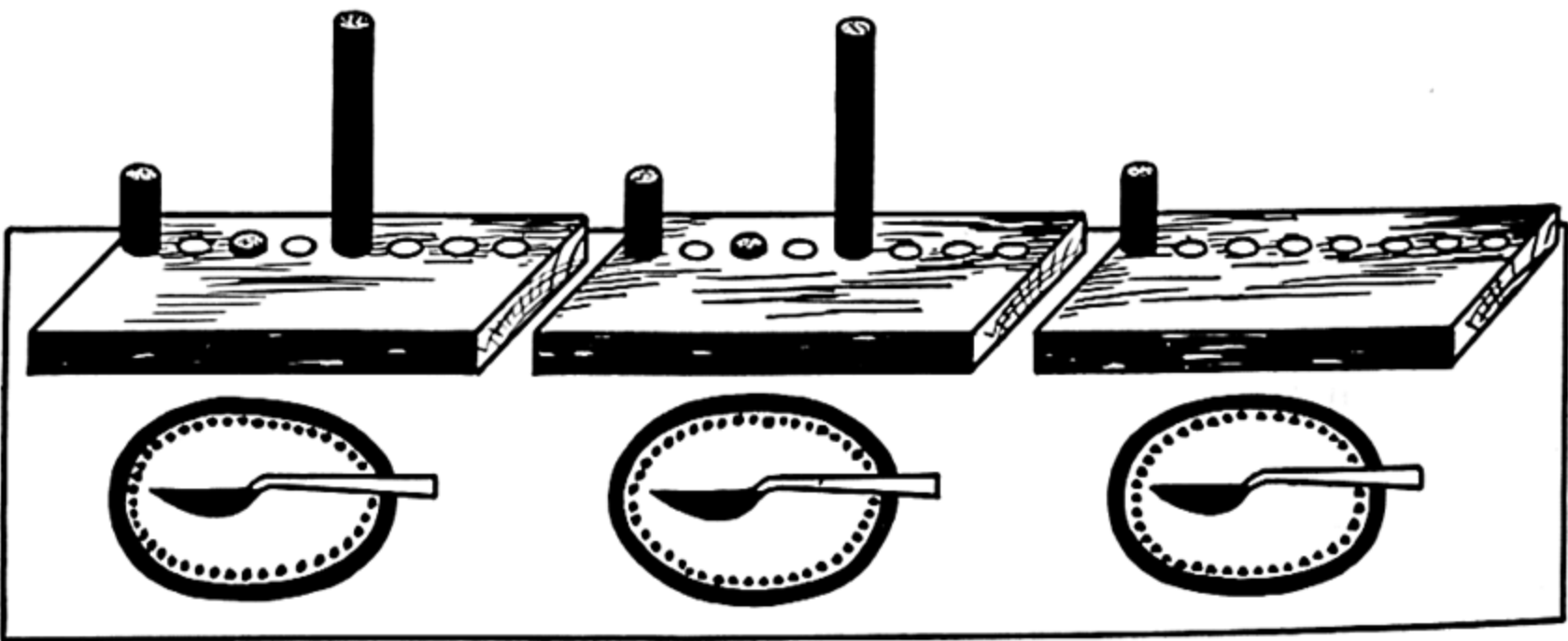


Fig. 118. Contributions to the Diet Made by Butter, Margarine, and Olive Oil

	Shares in Order on Blocks							
	Cal- ories	Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascor- bic Acid	Ribo- flavin
Butter, 1 tbsp.	1.00	0.0	0.1	0	3.0	Trace	0	0.0
Margarine, 1 tbsp.	1.00	0.0	0.1	0.0	3.0	0.0	0	0.0
Olive oil, 1 tbsp.	1.00	0	0	0	0	0	0	0

vitamin A, and such animal fats as are used in butter substitutes have relatively little. But most margarines on the market today have vitamin A added in the process of manufacture in amounts which make them the equivalent of average butter in this respect. One tablespoon of butter or margarine contributes to the diet 1 calorie share and 3 vitamin A shares; 1 tablespoon of olive oil, only 1 calorie share as shown in Fig. 118. In contrast 1 tablespoon of cod liver oil contributes 1 calorie share and 60 vitamin A shares.

In some parts of the world cod livers, richer sources of vitamin A than butter, are a staple article of the diet. But in this country, cod liver oil is used separately from other food as its flavor does not generally commend itself to adults, though young children seem to like it. The administration of cod liver oil to young children for the sake of its antirachitic vitamin has the additional advantage of increasing the intake of vitamin A. It is often better household economy to buy milk and margarine than to spend the same amount of money for cream or butter. In margarines, refined vegetable oils, such as cottonseed, coconut, and peanut, and oils derived from beef or lard are so combined or treated as to produce the desired hardness and are churned with milk or milk and butter to improve flavor and texture. As has been said, most of them now have added vitamin A. If more milk, green vegetables, and eggs can be bought by substituting such a product for butter, the diet will be improved in many respects.

Section 2. SUGARS AND OTHER SWEETS

The common food sugars are cane sugar or sucrose, milk sugar or lactose, malt sugar or maltose, glucose or dextrose, and fructose or levulose. Cane sugar of commerce is derived from the sugar cane and sugar beet. Milk sugar differs chemically from cane sugar, being less sweet, less easily dissolved in water, and less easily fermented. Malt sugar is made by the partial digestion of starch. Glucose occurs widely in nature but is obtained commercially by chemical treatment of starch. It does not appear in the food market as pure glucose but as "commercial glucose" or "corn syrup" which contains dextrin, glucose, and maltose. It is not very sweet, and table syrups made from it are flavored with the sweeter refiner's syrup from the manufacture of white cane sugar. Fructose occurs in many fruits, but honey is the only common food containing a high percentage. Honey contains nearly equal proportions of fructose and glucose plus a little dextrin and sucrose. Its flavor comes from substances found in minute quantities in the nectar of the flowers from which it is made. It has in addition traces of mineral matter and of ascorbic acid and riboflavin.

Maple syrup and maple sugar consist of the concentrated sap of the sugar maple and contain a certain amount of mineral matter as

well as flavoring substances, the yield of calcium by the syrup being 2.4 shares and of iron 2.9 shares per 100 calories. They are lacking in all vitamins.

Molasses is the mother liquor remaining after the removal of part of the cane sugar from the boiled-down juice of the sugar cane. In addition to the sugar it contains, it has considerable mineral matter, yielding 5.0 shares of calcium and 6.8 shares of iron per 100 calories.

Mixed syrups of various kinds are on the market and their ingredients may be learned from their labels.

Cane sugar resembles fat in being a concentrated form of body fuel, but differs from it in its effect on appetite and digestion. Two tablespoons of granulated sugar will yield 100 calories and can be eaten in a meal without adding perceptibly to the volume of food consumed.

A comparison of the contributions of 100-calorie portions of cane sugar, cane molasses, and honey is given in Fig. 119.

As body fuel, any kind of sugar is interchangeable with starch, calorie for calorie. In the process of digestion, starch is converted to sugar and nowadays much cornstarch is turned into glucose (corn syrup) before it is ever eaten. Sugar and starch are both delivered to the blood stream from the alimentary tract as simple sugars, glucose, fructose, etc. But no one would agree that starch and sugar are interchangeable in the menu; in fact we constantly add sugar to starch! The real reason for eating sugar is its sweetness. "Sweeter than honey in the honeycomb" is a time-honored phrase of high appreciation. How many things lose their zest when sugar is lacking! Sugarless tea, coffee, cocoa, breakfast cereals, stewed fruits, are acceptable to many, but cake and cookies, pie and pudding are unthinkable without sweetness. The bakery, the candy shop, and the soda fountain bear abundant testimony to our love of sweets. During the years 1947-53 the people of the United States consumed an average of 108 pounds per person of sugars and syrups per year, or over $\frac{1}{4}$ pound daily—what is this doing to the American dietary?

If too much sugar is allowed to displace other foods the diet will be deficient in the building and regulating materials which sugar lacks. To use the least sugar which will produce an acceptable flavor is a good rule. Sugar creates an appetite, not for other foods, but for itself. The candy eater asks for more candy, not for bread and

butter; the cake eater scorns the innocuous mildness of junket. Children who are allowed to eat candy whenever they feel like it are likely to be undernourished because the candy spoils their appetite for the foods they need for growth. Also such overindulgence in sugar may have a deleterious effect on their teeth.

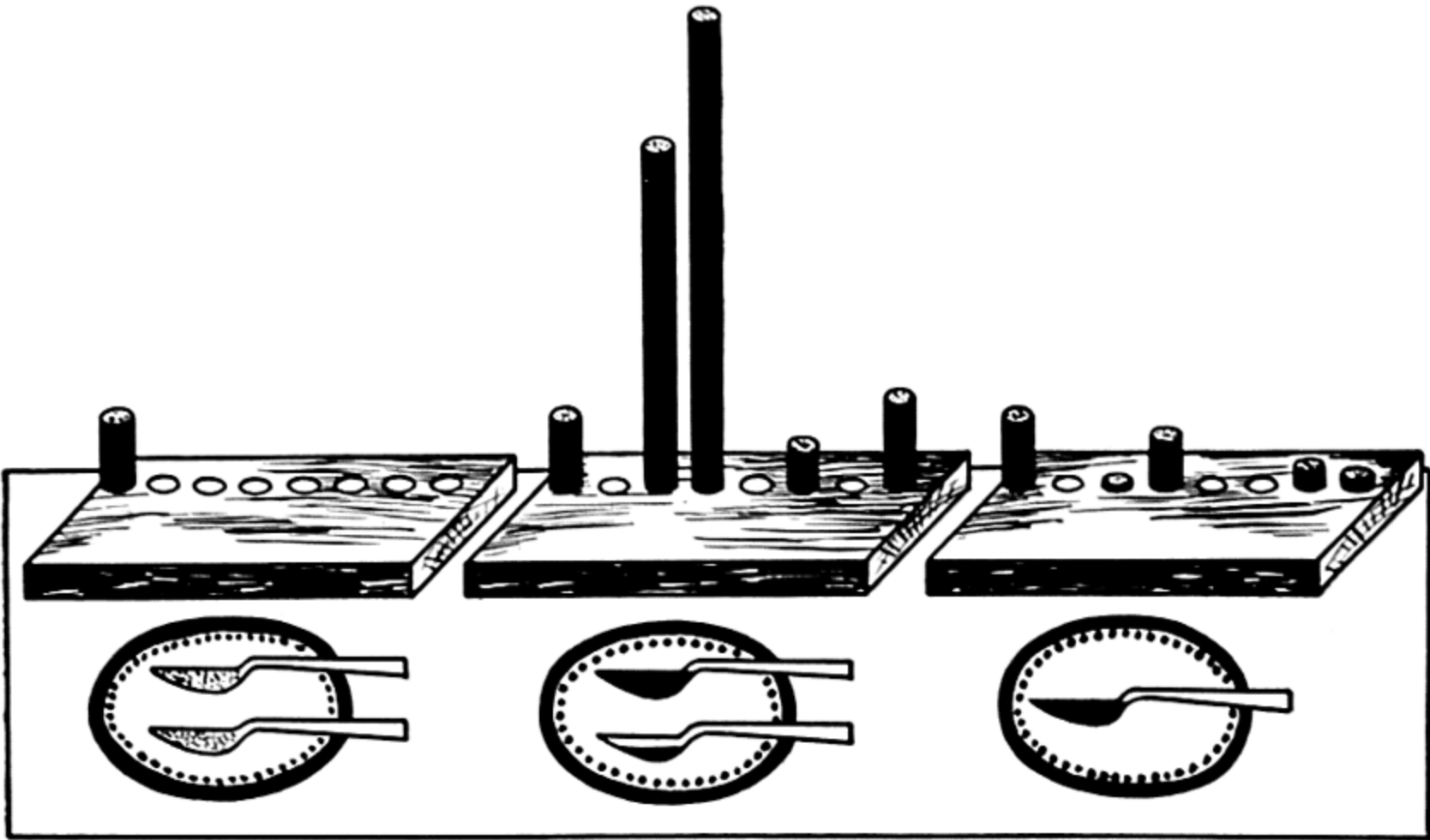


Fig. 119. Contributions to the Diet Made by Sugar, Molasses, and Honey

	Shares in Order on Blocks							
	Cal- ories	Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascorbic Acid	Ribo- flavin
Sugar, 2 tbsp.	1.00	0	0	0	0	0	0	0
Molasses, 2 tbsp.	1.00	0	5.0	6.8	0	0.6	0	1.4
Honey, 1 tbsp. rounded	1.00	0.0	0.1	0.8	0	Trace	0.4	0.2

Sugar taken alone on an empty stomach is directly irritating to the mucous lining, from which it abstracts water just as a piece of candy held in the cheek causes it to “pucker.” Hence the best place for sweet food is at the end of a meal, when it will be diluted, so to speak, by the food already consumed, and when it will not come directly into contact with the stomach wall.

Sugar taken in dilute form, as in sweet fruits, or as a sweetener for the juice of acid fruits like lemon and grapefruit, is not irritating to the stomach and should be quickly digested and absorbed. For those who engage in severe muscular activity, as athletes, or very

active older boys and girls, some sugar taken in this way may be beneficial, especially if the intervals between meals are long.

As commonly used, i.e., taken freely with butter over hot biscuits, griddle cakes, waffles, and the like, honey and table syrups are a menace to digestion if indulged in too frequently.

Molasses, carrying significant amounts of calcium, may be chosen with some advantage as a sweet for growing children in preference to cane sugar or syrups, if the amount of milk which can be obtained is not ideal. It must be remembered, however, that it takes 5 tablespoons of molasses to furnish as much calcium as 1 glass of milk. Molasses is an even better source of iron than of calcium and its iron has been found to be efficiently utilized. Hard molasses cookies, especially when made with whole wheat flour or with part of the wheat flour replaced by rolled oats, are an excellent sweet for children if used in moderation at the end of a meal.

Summary

Fats and sugars are primarily sources of fuel. Milk fat, whether cream or butter, is rich in vitamin A and on this account is of higher value than other natural food fats. Fat adds to the palatability of food and extends the range of culinary products greatly. It tends to retard digestion somewhat, giving a feeling of satisfaction after eating, but if used in excess, may delay digestion too much.

Sugars and other sweets owe their place in the diet to the popularity of their flavor. Contributing calories only, sugar can be replaced except as regards flavor and the part it plays in various culinary operations. Wise use implies great moderation as to quantity and care as to the time of eating sweets. Corn syrup and cane sugar yield calories only, while molasses, a concentrated vegetable juice, is rich in calcium and iron.

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Adequate Diet for Adults

Many factors enter into the food problem as it appears in everyday life. In the same household there are generally people of different food requirements. The baby cannot be fed like the five-year-old, nor the five-year-old like the high school belle, nor she like her football-playing brother. The fare which best suits the school teacher is held in scorn by the farm laborer whose energy needs are twice as high. To use the same food resources for all and to make adjustments which assure each a palatable, digestible, and adequate diet calls for knowledge and skill in the apportionment of the various items on the menu.

But this is not all. There are other problems arising from the environment. Eating is a social matter. When the family is away for the day, the housemother may be quite content with a luncheon of bread and milk in the kitchen, but when the group returns she feels impelled to put on the dinner table a more imposing array of foods, for dining is a social function important to the higher life of the circle and there is a laudable desire to make the food worthy of the occasion. Furthermore, friends are entertained with food. Seldom is the guest allowed to depart without the hospitable offer of something to eat, not because he needs nourishment, but because this is a form of entertainment held in high esteem. In apportioning the family food money one has to consider, in addition to the cost of actual nourishment, how much must be added to meet the social ideals of the family itself, and how much for the entertainment of friends according to the standards of the community.

It is not within the scope of this chapter to deal with the broader social aspects of the food problem. The aim is rather to show how

Adequate Diet for Adults

one may use knowledge of body requirements for the various dietary essentials and of the nutritive properties of common food materials to formulate a workable scheme for daily living, steering clear of the Scylla of perpetual calculation or worry and at the same time avoiding the Charybdis of eating according to the whim of the moment regardless of future welfare. Every person should have a simple program to care for routine food needs systematically and effectively. To show how such programs may be formulated and tested is the main object of this chapter.

The analogy between building a diet and building a house is remarkably close. "Specifications" must be furnished by one who understands the whole building process. The man who has money enough goes to an architect and puts the whole matter in his hands. A special plan is made to meet his individual needs. So a man whose life depends upon a diet containing a specified number of grams of protein, fat, and carbohydrate for every meal, with no margin for mistakes or indiscretions, is fortunate if he can put his case into the hands of a professional dietitian who will assume responsibility for all details.

But this specialized service is too costly for the majority. Another way to get a house is to "shop around" for plans of various sorts made by good architects for books or magazines. These can be bought with full specifications at a nominal cost; and if one can be found approximating the builder's ideal it will be far better than an untrained person's plan. Similarly, one may ask a dietitian to make a set of menus and quantitative specifications for a diet to be followed day by day by the person or group for whom it is planned. An institution may have sets of such plans for various seasons of the year, each repeating every three or four weeks. The chief objection is the danger of too great monotony and too little adjustment to individual needs.

There is still a third way of getting a house. Certain firms supply units already built and easily fitted together and it is possible to select those which make the sort of house the buyer wishes. By choosing as many wall units as needed for a house of the desired size, the main outline is determined. One may then pick out any one of several styles of doors and windows, of porches and ells, of dormers for the roof, and assemble them according to his taste. The final result may not be as elegant as if each detail had had individual

attention, but the dwelling can be very serviceable and far more artistic than anything an ordinary person would produce by starting with raw materials and evolving his own plan.

We usually build a diet by this third plan. We assemble foods as we would units of a house. We do not buy calories, grams of protein, iron, etc.; we buy meat and potatoes, oranges and eggs, etc. With a little study of their characteristics they can be fitted together to make a satisfactory whole, that is, an adequate diet for healthy individuals under ordinary living conditions.

A Diet for a Moderately Active Man at Moderate Cost

We have said in Chapter 20 that milk is a great protector of the diet at almost every point. It is of unique importance for calcium, an outstanding source of riboflavin, and a significant source of vitamin A and protein. Even in an adult diet, therefore, a liberal amount of milk should be included at all times—at least a pint a day.

Vegetables and fruits deserve a definite place in the diet because of the mineral elements and vitamins which they furnish, and also because of their laxative properties. Green vegetables, carrots, citrus fruits, tomatoes, potatoes, and cabbage are particularly valuable and should be used frequently.

The amount of eggs, meat, poultry, and fish to be used is determined partly by their nutritive value, partly by their flavor and ease of preparation for the table, and partly by cost. As has already been shown in Chapter 23, meats are relatively expensive in comparison with their nutritive return. To get a good diet at low cost, it is best to increase the milk and decrease the meat. Eggs and meat are much alike in their nutritive return when compared weight for weight excepting that eggs contribute considerable vitamin A and calcium in which meat is poor.

The foods from the cereal grains are valuable as sources of energy and protein; and if whole grain or enriched, they are good sources of iron, thiamine, and riboflavin. They are the most economical items in the diet, and the proportion used depends largely upon the amount of money available for food. As much as one-half of the total calories of an adult man's diet may be secured from this group of foods.

Fats and oils, because of their flavor and "staying power" as well as their high number of calories per pound, are important in a good

diet. When other sources of vitamin A are limited, it is desirable that much of the fat be butter or fortified margarine unless a fish liver oil or capsule is used regularly.

Sugars, while adding to the palatability of the diet, contribute fuel only and must not constitute a high proportion of the total calories or there will be danger of shortage of mineral elements and vitamins and also danger of digestive disturbances.

A good diet at moderate cost can be easily planned by following daily the simple rules for the selection of foods given below:

- 1 pint milk
- $\frac{1}{2}$ to $\frac{3}{4}$ cup orange, grapefruit, or tomato juice or their equivalent in fresh fruit
- $\frac{1}{2}$ to $\frac{3}{4}$ cup of a green or yellow vegetable
- 1 potato
- 1 egg daily or at least 3 or 4 per week
- 4 to 5 ounces of meat, poultry, or fish
- 4 to 6 slices of whole wheat or enriched bread or equivalent
- Other foods such as cereals, fats, sweets, and additional vegetables and fruits to meet the calorie requirement

Using these simple rules as a guide in the selection of foods for the moderately active man menus such as the following can be planned.

A DAY'S MENUS FOR A MODERATELY ACTIVE MAN

<i>Breakfast</i>	<i>Luncheon</i>	<i>Dinner</i>
Orange juice, $\frac{3}{4}$ cup	Vegetable plate with	Steak, round
Rolled oats, 1 cup	poached eggs on	Baked potato
cooked; milk, $\frac{1}{2}$ cup;	toast	Scalloped tomatoes
sugar, 2 tsp.	Bread, whole wheat, 3	Lettuce salad with French
Toast, enriched bread,	slices with butter or	dressing
3 slices with butter	margarine, 1 tbsp.	Rolls, 2, made with en-
or margarine, 1 tbsp;	Apricot meringue pie,	riched flour
jam, 2 tbsp.	4 $\frac{1}{2}$ " sector	Butter or margarine, 2
Coffee; top milk,* 2 tbsp.;	Milk to drink, 1 glass	tbsp.
sugar,* 2 tsp.		Spanish cream with
		cherry sauce
		Coffee; top milk,* 2 tbsp.;
		sugar,* 2 tsp.

* If not needed for coffee, add to the cereal or fruit.

It will be noted that in these menus half of the pint of milk has been used for drinking and the other half for cereal, coffee, and des-

sert. The fruit juice and part of the bread are included in the breakfast menu. The green vegetable—in this case, kale—and the egg will be found in the luncheon menu, and in the dinner menu, the potato and meat along with more of the bread. The additional items given in these menus provide for the extra calories needed to meet the 3,200-calorie requirement.

Applying this plan to a particular case, we may take a man weighing 65 kilograms or 143 pounds, leading a moderately active life as a civil engineer, and needing a total of 3,200 calories per day. An adequate diet for him would furnish 32 shares each of calories, protein, calcium, iron, vitamin A, thiamine, ascorbic acid, and riboflavin.

Having planned the three meals with the simple rules of nutrition in mind it might be well at this time to test the adequacy of these rules to see whether or not the foods suggested do provide enough calories, protein, calcium, iron, vitamin A, thiamine, ascorbic acid, and riboflavin to meet the daily recommended allowances. A list of the actual foods needed for the preparation of these menus with the contributions of each food worked out in shares will be found on page 436.

It will be noted at a glance that the milk contributes a little more than two-thirds of the total calcium recommended and the other foods with the exception of kale contribute only very small amounts of calcium. The milk at the same time furnishes more than one-half of the recommended allowance of riboflavin. This is much more riboflavin than any other one food contributes.

The outstanding contribution of the orange juice is ascorbic acid. In the amount provided in this dietary it more than meets the recommended daily allowance and the smaller amounts contributed by the other foods allow for a desirable surplus, the total shares of ascorbic acid being almost three times the 32 shares recommended.

The squash and kale together provide more than twice the recommended allowance for vitamin A and with the other foods making large contributions of this dietary essential, namely, the milk, apricots, tomatoes, butter, and eggs, the total amount of vitamin A is far in excess of that recommended. This is desirable in the light of the findings of Batchelder who reported increasing beneficial effects in rats receiving amounts of vitamin A up to four times the minimum requirement. The kale at the same time makes rather large con-

tributions toward meeting the requirement for calcium, iron, ascorbic acid, and riboflavin.

The potato, although it makes no such startling contributions as the foods previously mentioned, is a good source of iron, thiamine, and ascorbic acid. If one runs his eye down the column for thiamine it will be appreciated that none of the foods in this dietary makes an outstanding contribution of this dietary essential and that we are dependent upon the smaller contributions of a number of foods for our supply of thiamine. The potato thus takes an important place in the daily dietary and offers at the same time an opportunity for cutting costs since it is one of the less expensive vegetables.

In this particular day's dietary, because of the egg used for the pudding and the meringue on the pie, more than one egg would be needed. In comparing the contributions of the eggs with those of the other foods it will be noted that they are a good source of protein, iron, vitamin A, and riboflavin. Because it is difficult to obtain adequate amounts of iron and riboflavin it may be said that the eggs are outstandingly important because of these contributions.

The chief contribution of the meat is protein. It furnishes more protein than any other one food, providing almost half of the recommended allowance for the day. It also excels all other foods in this dietary as a source of iron and may be considered a good source of thiamine and riboflavin.

The seven slices of bread plus the two enriched rolls, although they appear as separate items, should be considered collectively. If treated in this way it will be found that the bread and rolls provide about one-half of the recommended daily allowances for iron and thiamine. If the contributions of the breakfast cereal are added to those of the bread, the cereals taken together contribute one and a half times as much iron as the meat and seven and a half times as much thiamine—and at a much lower cost.

Looking back again at the simple rules for the choice of foods it will be appreciated that if the suggested foods are included first in planning the day's menus, the recommended allowances for specific nutrients will be practically taken care of, and the other foods making up the additional calories provide desirable surpluses of the minerals and vitamins.

Another way of planning a diet is to select foods so that the calories contributed by milk, cereals, vegetables and fruits, fats, sugar,

and the meat, eggs, fish, cheese group will follow the percentage distribution suggested in Table XVI(d) in the Appendix. This is also an easy way to evaluate a diet.

A Diet for a Moderately Active Woman at Moderate Cost

The problems arising in the feeding of the moderately active woman are not very different from those connected with the feeding of the moderately active man. A woman weighing 55 kilograms or 121 pounds, leading a moderately active life as a homemaker and doing her own housework, would need about 2,300 calories per day. If we refer to Table I(a) in the Appendix we will see that an adequate diet for her should furnish 23 shares of calories, 27 of protein, 32 each of calcium, iron, and vitamin A, 24 of thiamine, 30 of ascorbic acid, and 28 of riboflavin. Since her daily allowances are so much like those for the standard man, we can be guided by the same simple rules as were followed for the choice of foods for him and with these in mind, suitable menus for one day for her might approximate the following:

A DAY'S MENUS FOR A MODERATELY ACTIVE WOMAN

<i>Breakfast</i>	<i>Luncheon</i>	<i>Dinner</i>
Grapefruit, one half	Tomato consommé	Pork chop with apple
Puffed wheat, enriched, with top milk and sugar	with whole wheat crackers	sauce
Poached egg on toast (en- riched bread)	Salmon salad	Potato, baked
Butter or margarine, $\frac{1}{2}$ tbsp.	Bread, whole wheat, 1 slice with butter or fortified margarine, $\frac{1}{2}$ tbsp.	Mustard greens ^b
Coffee; top milk,* 2 tbsp.; sugar,* 2 tsp.	Fruit cup	Lettuce with French dress- ing
	Milk, 1 glass	Date muffins, 2
	Tea, if desired	Butter or margarine, 1 tbsp.
		Orange milk sherbert
		Coffee; top milk,* 2 tbsp.; sugar,* 2 tsp.

* See footnote, page 433.

^b Or other dark green leaves.

As in the case of the menus planned for the average man only one-half of the milk has been planned for drinking, the rest being needed for cereal, milk sherbet, and the coffee. On another day when the menus planned did not happen to call for cereal or a milk dessert, the two glasses of milk could be saved for drinking.

In these menus fresh grapefruit has been planned for breakfast in place of fruit juice; potato, mustard greens, and meat are used for

dinner; and the egg is eaten for breakfast. The bread has been distributed throughout the three meals.

The simple rules for the choice of foods have thus been followed in the planning of these menus and if we examine the contributions of the individual foods and the total values of the day's dietary as given on page 439 we will see that it is well fortified with a surplus of each of the specific nutrients recommended.

Looking at the individual contributions of the foods we see that here again milk is the only food making a large contribution to the calcium requirement. The milk and the pork chop are the outstanding sources of protein, the mustard greens of vitamin A and iron, the pork chop of thiamine and iron, the grapefruit and orange of ascorbic acid, and the milk of riboflavin.

See Table XVI(d) in the Appendix for a desirable distribution of calories in diets for adults.

A Diet for a Sedentary Man

The plans so far suggested have been for persons leading a life in which most of the working day is spent in at least moderate muscular activity, as walking, lifting fairly heavy materials, and the like. But in a modern city, one may ride to work, sit all day at one's desk, or engage in no muscular activity greater than standing or walking slowly about from time to time, having luncheon in the building in which one works, riding home at night, sitting down to dinner, and afterwards spending the evening sitting, whether reading at home, attending the theater, or looking at television. How many calories are spent under such circumstances? And what changes in the program are required to adapt it to the lower calorie expenditure?

The first thing to remember is that the chief item to be reduced is the total calories. By referring to Table III(b) in the Appendix, it will be noted that the calorie allowance for a sedentary man weighing 65 kilograms (143 pounds) is 2,500 calories or 25 shares. By referring to Table I(b) in the Appendix, the shares for the other nutrients corresponding to the 2,500-calorie level will be 32 each for protein, calcium, iron, vitamin A, ascorbic acid, and riboflavin, and 26 for thiamine.

Selection of food materials is now a comparatively easy matter and with the simple rules as our guide we can make our choices from

A DAY'S DIETARY FOR A MODERATELY ACTIVE WOMAN AT MODERATE COST

Shares Contributed to the Diet

<i>Foods</i>	<i>Measure</i>	<i>Cal- ories</i>	<i>Pro- tein</i>	<i>Cal- cium</i>	<i>Iron</i>	<i>Vita- min A</i>	<i>Thia- mine</i>	<i>Ascorbic Acid</i>	<i>Ribo- flavin</i>
Milk, pasteurized	1 pint	3.33	8.4	23.1	0.9	6.1	3.5	4.3	17.6
Grapefruit	$\frac{3}{4}$ medium	1.33	0.8	2.9	2.8	0.4	5.3	56.8	4.0
Banana	$\frac{1}{2}$ banana	0.20	0.1	0.1	0.4	0.6	0.2	0.9	0.2
Orange	1 small	0.50	0.5	1.5	1.2	1.6	1.8	25.2	1.1
Apple, cooked	$\frac{3}{4}$ large	0.33	0.1	0.1	0.4	0.3	0.5	0.3	0.3
Dates	4 dates	0.80	0.3	0.8	1.4	0.3	0.5	0	0.3
Tomatoes, canned	$\frac{3}{4}$ cup	0.33	0.9	0.4	2.3	11.8	2.1	11.8	1.1
Celery	$\frac{3}{8}$ cup	0.09	0.3	1.0	0.7	0	0.5	1.5	0.4
Potato, baked	1 medium	1.00	1.2	0.5	2.1	0.1	2.2	7.7	1.0
Mustard greens, cooked	$\frac{1}{2}$ cup	0.16	0.8	6.2	5.4	32.2	0.8	13.5	2.5
Lettuce	$\frac{1}{2}$ head	0.15	0.6	0.9	1.3	2.5	1.4	4.7	1.2
Puffed wheat, added vitamins	$\frac{3}{4}$ cup	0.35	0.5	0.2	1.1	0	1.1	0	0.4
Bread, white, enriched	1 slice	0.63	1.0	0.7	1.1	0	1.2	0	0.8
Crackers, whole wheat	2 small	0.40	0.4	0.1	0.5	(0)	0.6	0	0.2
Bread, whole wheat	1 slice	0.67	1.3	1.1	1.6	0	1.7	0	0.7
Flour, enriched	$\frac{3}{4}$ cup	1.33	1.9	0.3	2.8	0	3.2	0	1.9
Pork chop, broiled	1 medium	2.93	9.9	0.4	6.8	(0)	14.4	0	4.2
Egg, cooked	1 medium	0.75	3.0	1.0	3.4	3.5	0.8	0	2.6
Salmon, canned	$\frac{1}{4}$ cup	0.75	3.6	2.3	0.8	0.5	0.2	0	1.1
Butter or margarine	2 $\frac{1}{2}$ tbsp.	2.50	0.1	0.3	0	7.5	Trace	0	0.1
Salad oil	2 $\frac{1}{2}$ tbsp.	2.33	0	0	0	0	0	0	0
Sugar	5 tbsp.	2.50	0	0	0	0	0	0	0
Totals from diet		23.36	35.7	43.9	37.0	67.4	42.0	126.7	41.7
Recommended daily allowances		23.00	27	32	32	32	24	30	28

a wide variety of available foods. Suitable menus for this man might well be as follows:

A DAY'S MENUS FOR A SEDENTARY MAN

<i>Breakfast</i>	<i>Luncheon</i>	<i>Dinner</i>
Orange juice	Oyster stew with	Tomato juice
Shredded wheat biscuit	oyster crackers	Roast lamb
with banana, milk,	Salad, orange and	Potato, pan roast
sugar	grapefruit with	Peas
Coffee with top milk ^a	dates	Carrot strips
and $\frac{1}{2}$ tbsp. sugar ^a	Blueberry muffin	Bread, enriched
Toast, whole wheat,	Butter, $\frac{3}{4}$ tbsp.	Butter, 1 tbsp.
2 slices	Cream cheese	Orange custard
Butter, $\frac{3}{4}$ tbsp.	Milk, 1 glass	Coffee with top milk ^a
Soft boiled egg	Tea, if desired	and $\frac{1}{2}$ tbsp. sugar ^a
Jam, $1\frac{1}{2}$ tbsp.		

^a See footnote, page 433.

That this selection of foods will meet the requirements is shown by the total contributions of the foods making up the dietary (see page 441). Without departing from the common plan of food selection, a diet of excellent quality has been achieved and each specific nutrient is well provided for even though the calories total only 2,501.

A Diet for an Overweight Woman

The tendency to store fat increases as men and women grow older. It varies with individuals and, if hereditary, needs to be carefully watched. It is easier to begin a program of dietary control which is preventive of overweight than to take off extra pounds of fat which should not have been allowed to accumulate. Some of the problems of surplus calories have been discussed in Chapter 6. Here an attempt will be made to show how modern knowledge of nutrition makes it possible to adjust one's energy intake to one's energy needs without failing to meet the other dietary needs. In fact, the good reducing diet is unexcelled in quality by any other if rightly chosen. The aim of the good reducing diet is to provide generously every essential but calories. The reason calories can be limited is that there are plenty of calories in the body fat, which will not be used if a plentiful supply comes in with every meal.

Here the situation is quite different from those preceding, because although the calorie intake is reduced considerably, about the same number of shares of other nutrients must be provided. This will be fully appreciated by looking up the recommended allowances for a

A DAY'S DIETARY FOR A SEDENTARY MAN

Shares Contributed to the Diet

<i>Foods</i>	<i>Measure</i>	<i>Cal- ories</i>	<i>Pro- tein</i>	<i>Cal- cium</i>	<i>Iron</i>	<i>Vita- min A</i>	<i>Thia- mine</i>	<i>Ascorbic Acid</i>	<i>Ribo- flavin</i>
Milk, pasteurized	1 pint	3.33	8.4	23.1	0.9	6.1	3.5	4.3	17.6
Orange juice, fresh	4 oz. glass	0.54	0.5	0.9	1.0	(1.5)	1.9	27.8	1.2
Banana	1 medium	1.00	0.7	0.4	1.8	3.1	1.0	4.7	1.2
Jam	1½ tbsp.	0.84	0.1	0.2	0.3	0.0	0.2	0.8	0.2
Grapefruit	½ cup	0.20	0.1	0.4	0.4	0.0	0.8	8.6	0.6
Dates	2 dates	0.40	0.2	0.4	0.7	0.2	0.2	0.0	0.2
Blueberries	1 tbsp.	0.05	0.0	0.1	0.2	0.1	(0.0)	0.6	(0.0)
Orange	½ medium	0.44	0.4	1.3	1.1	1.4	1.6	22.6	1.0
Tomato juice	½ cup	0.25	0.6	0.3	(1.3)	8.0	1.2	8.1	0.7
Potato, roasted	1 large	1.50	1.8	0.9	3.6	0.3	3.6	12.3	1.5
Peas, cooked	½ cup	0.56	1.9	0.7	4.0	3.7	4.0	5.2	2.2
Carrot, raw	12 thin strips	0.12	0.1	0.4	0.5	21.8	0.4	0.9	0.4
Bread, white, enriched	2 slices	1.26	2.0	1.4	2.2	0	2.4	0	1.6
Bread, whole wheat	2 slices	1.36	2.6	2.2	3.2	0	3.6	0	1.6
Shredded wheat	1 biscuit	1.00	1.4	0.5	2.6	0	1.2	0	0.6
Crackers, oyster	12 crackers	0.52	0.6	0.1	0.3	(0)	0.2	(0)	0.1
Flour, enriched	3 tbsp.	0.75	1.1	0.2	1.5	0	1.8	0	1.1
Oysters	½ cup	0.67	3.9	3.0	12.5	1.3	3.9	1.1	5.6
Lamb, roasted	2 slices	2.00	8.4	0.4	5.8	0	2.0	0	3.6
Cheese, cream	1 ounce	1.05	1.3	0.7	0.3	(2.6)	(0.0)	(0)	1.3
Egg	1½ eggs	1.25	5.0	1.7	5.7	5.8	1.3	0	4.3
Butter or margarine	3½ tbsp.	3.67	0.2	0.4	0	11.0	Trace	0	0.1
Salad oil	½ tbsp.	0.50	0	0	0	0	0	0	0
Sugar	3½ tbsp.	1.75	0	0	0	0	0	0	0

Totals from diet

25.01 41.3 39.7 49.9 66.9 34.8 97.0 46.7

44 Recommended daily allowances

25.00 32 32 32 32 26 32 32

reducing diet for a woman (see Table I(b) in the Appendix). Although with 1,200 calories or 12 shares, adequate protein, mineral elements, and vitamins can be provided for the reducing diet, if the foods are carefully selected, many people prefer to have a few more calories and reduce more slowly. Therefore, the calories suggested range from 1,200 to 1,400. However, the dietary suggested here is for 1,200 calories, which, with a moderate degree of activity, should result in a loss of about 2 pounds a week. In Table I(b) in the Appendix the following allowances expressed in shares are recommended: 32 each for calcium, iron, and vitamin A; 20 for thiamine; 30 for ascorbic acid; and 28 for riboflavin. The protein should be calculated on the basis of the weight desired, and assuming a body weight of 60 kilograms (132 pounds), the allowance for protein would be 29 shares.

This means that the same simple rules of food selection take on even greater importance. We have already learned that by following them, all of the specific nutrients will be provided, but in this case the choices must be made from foods of low calorie value. In other words every food included (with one or two exceptions) must be justified by the fact that it carries at least twice as many shares of one or more of the mineral elements and the vitamins as it does of calorie shares. A helpful thing to do here would be to study the share table in the Appendix and list the foods measuring up to these specifications. With a list such as this to choose from along with the simple rules, menus such as those suggested below might be planned. The contributions in shares of the foods needed for the preparation of these menus will be found on page 444.

A DAY'S MENUS FOR AN OVERWEIGHT WOMAN

<i>Breakfast</i>	<i>Luncheon</i>	<i>Dinner</i>
Orange, sliced	Lettuce, peas, and egg	Tomato juice
Toast, whole wheat,	salad with lemon	Roast beef
1 slice	juice dressing	Potato
Butter, 1 tsp.	Crackers and cheese	Spinach
Coffee, black ^a	Milk, skim, 1 glass	Carrot strips
Milk, skim, 1 glass		Bread, whole wheat, 1
		slice
		Butter for bread and
		vegetables, 2 tsp.
		Banana, baked
		Coffee, black ^a

^a If desired.

Adequate Diet for Adults

It will be noted that to get as much nutritive value with the fewest possible calories from milk, skim milk has been selected instead of whole milk. This gives more opportunity for the enjoyment of a variety of foods, and the vitamin A which would have been obtained from the whole milk is best secured from green vegetables or a concentrated source, such as halibut liver oil or a fish liver oil concentrate.

The vegetables chosen are excellent sources of vitamins. If desired, larger quantities of leafy vegetables can be used. In fact all green vegetables and all succulent ones such as celery and tomatoes can be eaten in whatever quantity is desired if no fats are added to season them, as their calorie value is so low. Salad dressing of excellent flavor can be made with lemon juice, which yields only a few calories. Orange juice yields more calories than tomato juice or grapefruit juice which can be substituted at pleasure and used in larger measure. When sweetening of grapefruit juice is desired, saccharin or sucaryl (noncaloric sweeteners) can be used instead of sugar. A little fat helps to give the diet staying power as well as enhancing the attractiveness of such foods as bread and potatoes. The whole grain or enriched breads are the better choice, but the amount of bread must be limited. Thiamine should be obtained from bran, wheat germ, yeast, or some other special source of this vitamin. Sugar gives nothing but calories and is best avoided, as sweetening can be accomplished with noncaloric sweeteners. A person who needs a low-calorie diet should cultivate the habit of enjoying other flavors. Meats should be lean. Many calories are concealed in the fat of a sirloin steak or a pork chop. The all-round value of the egg is high in proportion to its calories, so that it is an excellent staple in a reducing diet.

See Table XVI(d) in the Appendix for a desirable distribution of calories in a reducing diet.

Diets for Older Folks

The simple rules given on page 433 for the selection of an adequate diet can be followed in planning diets for older folks. In Table III(b) in the Appendix will be found suitable calorie allowances for older men and women of different body weights and ages based on the National Research Council Recommended Allowances (1953). The recommendations for specific nutrients according to calorie requirements are given in Table I(b) in the Appendix. Suggestions for

A DAY'S DIETARY FOR AN OVERWEIGHT WOMAN

Shares Contributed to the Diet

<i>Foods</i>	<i>Measure</i>	<i>Cal- ories</i>	<i>Pro- tein</i>	<i>Cal- cium</i>	<i>Iron</i>	<i>Vita- min A</i>	<i>Thia- mine</i>	<i>Ascorbic Acid</i>	<i>Ribo- flavin</i>
Milk, skim ^a	1 pint	1.74	8.4	24.2	1.2	(0.2)	4.8	4.2	17.6
Orange	1 medium	0.70	0.7	2.0	1.6	2.2	2.4	35.0	1.6
Banana, baked	1 medium	1.00	0.7	0.4	1.8	3.1	1.0	3.1	1.2
Tomato juice, canned	$\frac{1}{2}$ cup	0.25	0.6	0.3	(1.3)	8.0	1.2	8.1	0.7
Spinach, cooked	$\frac{3}{4}$ cup	0.35	2.1	*	7.2	102.0	2.1	17.4	5.4
Potato, baked	1 medium	1.00	1.2	0.5	2.1	0.1	2.2	7.7	1.0
Peas, cooked	$\frac{1}{2}$ cup	0.56	1.9	0.7	4.0	3.7	4.0	5.2	2.2
Lettuce	$\frac{1}{4}$ head	0.15	0.6	0.9	1.3	2.5	1.4	4.7	1.2
Carrot, raw	5 thin strips	0.05	0.1	0.2	0.3	9.2	0.1	0.3	0.1
Bread, whole wheat	2 slices	1.36	2.6	2.2	3.2	0	3.6	0	1.6
Crackers, whole wheat	2 small	0.40	0.4	0.1	0.5	(0)	0.6	(0)	0.2
Beef, sirloin, roasted	1 slice	1.50	5.7	0.2	3.9	(0)	0.6	0	1.8
Egg, boiled	1 medium	0.75	3.0	1.0	3.4	3.5	0.8	0	2.6
Cheese, American	1 slice	1.00	3.1	8.7	0.8	2.2	0.2	(0)	2.2
Butter or margarine	1 tbsp.	1.00	0.0	0.1	0	3.0	Trace	0	0.0
Sugar	1 tsp.	0.17	0	0	0	0	0	0	0
Lemon juice	2 tsp.	0.02	0.0	0.1	0.0	0	0.2	2.0	0.0
Totals from diet		12.00	31.1	41.6	32.8	139.7	25.2	87.7	39.4
Recommended daily allowances		12.00	29	32	32	32	20	30	28

^a Pasteurized.

* Not available.

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planning attractive menus are given below. It must be kept in mind that caution must be exercised in order to provide for good appetite and digestion and for ease of mastication. In some cases vitamin supplements may be desirable. For special suggestions see the bulletin by Lifquist, Cashin, and Davis in the references at the end of this chapter.

Suggestions for Menu Planning

It must never be forgotten that the administration of a diet is quite as important as the plan upon which it is built. Just as the work of the architect is only begun when the plans are drawn and must continue until he has accomplished the greater task of finding the materials and the workmen to translate his paper house into a worthy edifice, so the dietitian must select foods with reference to good quality and fair price, must see that they are cooked so that their nutritive values are conserved or enhanced and not depreciated, and must combine them into meals which are satisfying and wholesome. Furthermore, these meals must be served with regularity from day to day, so that the human machine may run smoothly, without wrench or strain so far as food is concerned. For a fuller discussion of the care of the digestive mechanism and adjustment to various problems related to feeding adult men and women the reader is referred to Rose's *Feeding the Family*. The following suggestions for the making of a good menu are taken from *Rose's Laboratory Handbook for Dietetics*, by Taylor and MacLeod, 5th edition, page 54:

"1. Conceive of the whole day as a unit, rather than the individual meal.

"2. Endeavor to distribute the protein, fat, and carbohydrate through the day, so that no meal will have a striking preponderance of one kind of fuel foodstuff. For example, meat served with macaroni and cheese concentrates the protein in one meal, potatoes with rice concentrate the carbohydrate, and fried potatoes and pie concentrate the fat.

"3. With the exception of a few such staples as bread, butter, and milk, try to avoid serving any food in the same form twice in the same day, and serve it preferably only once in any form.

"4. Try to avoid serving any food which gives character to a dish twice in the same meal, even in different forms. Do not, for instance, select tomato soup and tomato salad for the same meal.

"5. At each meal, seek contrasts between successive courses, a bland course being followed by a more highly flavored course, and vice versa, to give a pleasing rhythm.

"6. In each course pay attention to flavor, color, form, and texture. There are esthetic values in crisp crackers with soup, a green lettuce leaf on a salad plate, a red cherry on a rice pudding, a gelatin jelly turned from a graceful mold, or a slice of lemon with a serving of fish, and other combinations which exhibit pleasing contrasts.

"7. As the number of courses increases, decrease the number of dishes and size of the servings in each."

A Diet for an Adult at Minimum Cost

Many students who are struggling to maintain themselves in college are faced with the problem of how to attain a diet of optimum nutritive value at low cost. Economizing on food is only one of the many ways in which expenses must be cut and it is of interest to know that the cost of food can be reduced to an amazingly low level without lowering the standards of health, provided the food is chosen wisely. In fact, it is possible for one to live on an even higher nutritional level than formerly. In other words, it is not the size of the food budget which determines the nutritive quality of the diet but the wisdom with which one selects food.

Food costs include many items besides just the cost of the raw materials, such as the cost of fuel, rental, service, profit, and depreciation. Rooms with cooking and refrigerator privileges command more rent than similar rooms without such privileges. However, the additional rent is usually small compared with the amounts which can be saved by preparing one's own food. Even when one chooses to eat in self-service cafeterias or automats, the outlay is still greater than the cost of the food in the open market.

Students having rooms with these special privileges just mentioned can live rather well on an allowance of \$1.00 to \$1.25 a day for the raw materials at present city prices. If two students join forces they probably could purchase food for less than this by careful buying. With two to share the responsibility time could be saved in marketing and food preparation, and meals could be made more interesting because the purchasing can be done to better advantage. Also a good companion with whom to enjoy one's meals is often just the incentive needed. The acme of this is the cooperative house with its many

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opportunities for sociability along with those for economical buying.

If one has a room without refrigerator and cooking privileges, then the problem of keeping food is a great drawback. The choice of foods meeting these specifications is so limited that it is almost necessary to get at least one meal in the college cafeteria or in a neighboring restaurant. Hot dishes with plenty of calories should be chosen, such as meat and vegetable stews, Spanish rice, macaroni and cheese, meat and potato hash, baked beans, and hot soups, especially the cream vegetable or kidney bean soups. The breakfast and supper will have to be very simple. Only those foods which can be used in the same day or those which will possibly keep for a couple of days at room temperature should be purchased.

Certain so-called protective foods must be included daily and must be chosen from the standpoints of quantity, nutritive quality, and cost. Milk, of course, should head the list since no other food will give the same nutritive returns for so little money. At least a quart a day is a good amount to buy because it can be divided between the two meals to be eaten at home. Always ask for pasteurized milk when buying fresh milk. If one prefers to save still more money, a large can of evaporated milk can be purchased in place of the fresh since the nutritive quality is nearly the same as the fresh. One can also use the instant skim milk powder providing he has some other adequate source of vitamin A. Probably a 1-pound loaf of bread will be enough for two days unless one is engaging in more than the usual amount of activity and needs additional calories to maintain weight. There are several varieties to choose from, whole wheat, white enriched, rye, cracked wheat, or raisin bread. A small jar of peanut butter or occasionally a glass of jelly or jam can be purchased and will keep for some time without refrigeration. One can of orange juice, grapefruit juice, or tomato juice purchased every other day will provide the ascorbic acid required, or if fresh oranges fit the budget they can be used and occasionally an apple, banana, or other available fresh fruit can be substituted. Since the orange is far superior to the apple and the banana as a source of ascorbic acid it would be wise to favor oranges in choosing fresh fruit. For a little more variety, raisins, dried prunes, and apricots can be purchased since they can be washed and eaten dry or soaked in a little water until they soften sufficiently to be eaten. Soaking overnight should be long enough to make them palatable. If they can be purchased in

small enough quantity and at a sufficiently low price fresh vegetables which need no cooking, such as tomatoes, cabbage, carrots, and onions, may be used. However, one must not allow himself to carry these tempting foods to his room unless he feels sure that they can be eaten before spoiling. Remember always that there is no allowance on a limited budget for the wasting of food. A metal container of some kind should be obtained which will hold the food to be stored and keep it clean and sanitary.

The following list may serve as a guide when marketing on a limited budget and will at the same time protect against malnutrition.

(1) Orange juice ($\frac{1}{2}$ cup daily); grapefruit juice or tomato juice may be substituted occasionally.

(2) Milk, at least a pint a day (preferably a quart).

(3) Whole wheat or enriched bread, cereals, and crackers. These, with milk, should be the major portion of the diet.

(4) One raw vegetable daily; carrots, cabbage, spinach, yellow turnips are most satisfactory.

(5) Some fat; for example, fortified margarine or peanut butter.

(6) For further protection it is highly desirable to invest in a bottle of cod liver oil and take 1 teaspoon daily or use fish liver oil capsules. This should be regarded as additional health insurance.

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Food Needs of Mothers and Babies

“The baby owes nothing at all to his parents. He has no responsibilities, no duties. The parents owe everything to the baby. Their responsibility to him is complete. Their duties are endless. They are most solemnly bound to use every effort to keep him in good health and happy, to build up his constitution to fit him for the world, and to launch him upon the world. In time their responsibility lessens but it never disappears; whatever happens, it cannot end. In other words, we are bound to see that children are given the best opportunity to develop to the limit of their growth capacity.” If we accept this statement by Arnold Bennett as the modern baby’s bill of rights, we are solemnly bound to apply all the accumulated knowledge in regard to the nutrition of the growing organism to the problem of feeding the baby.

Good nutrition for the baby begins with the mother. During prenatal life growth goes on at a rate never equaled after birth. The profound effect of diet upon the well-being of the fetus has been repeatedly demonstrated in the case of laboratory animals and observations on human beings reveal similar effects. Among women in the Philippines suffering from beriberi (due to thiamine deficiency), it has been reported that 80 per cent of the pregnancies result in abortion or in death of the child during the first year of life. Reynolds and Macomber have reported cases of women in whom sterility was apparently cured by a change from a diet habitually low in vitamin A to one rich in it. The influence of a shortage of iodine upon the development of the embryo has been demonstrated not

only for various farm animals but also for the human species. Protracted undernutrition of mothers in Europe as a result of World War I resulted in a decrease in the weight of the newborn, in a lowering of the capacity for milk production, and in the appearance of rickets in the offspring.

The earliest convincing evidence we have of the influence of the nutrition of the mother during the prenatal period is that reported by Ebbs, Tisdall, and Scott.¹ They studied during the last three to four months of pregnancy 380 low-income women who had planned on being confined in the Toronto General Hospital. Those who were found to be on a poor diet were divided into two groups, one being continued on the poor diet as a control group and the other receiving supplementary foods to improve the quality of the diet. Those who were found to be already on moderately good diets made up the third group and their diets were improved through education only. The mothers on the good or supplemented diets enjoyed better health, had fewer complications, and proved to be better obstetrical risks. They had fewer miscarriages, stillbirths and premature births, and a lower incidence of illness in the babies up to six months, as well as fewer deaths resulting from these illnesses.

Several similar studies have followed this one of Ebbs and his associates. In 1942 and 1946 a committee of the People's League of Health of England reported the results of investigating the influence of the nutrition of expectant and nursing mothers on maternal and infant mortality and morbidity in a group of about 5,000 English women, 50 per cent of whom received supplements of mineral elements and vitamins while the other 50 per cent continued on their own diets. The incidence of toxemia was 30 per cent lower in the group receiving the supplements, and premature births were markedly reduced.

In 1943 and 1949 Burke, Stuart, and their associates reported the results of carefully planned studies of 216 women attending the prenatal clinics at the Boston Lying-in Hospital. Detailed studies of the nutritional status of the women were made at intervals during pregnancy and the physical condition of the infants at birth and within the first two weeks of life was carefully assessed. A significant

¹ Ebbs, J. H., Tisdall, F. F., and Scott, W. A. "The Influence of Prenatal Diet on the Mother and Child." *The Journal of Nutrition*, Vol. 22, page 515 (1941).

relationship was found between the physical condition of the infant and the diet during pregnancy. Premature births, stillbirths, and neonatal deaths occurred much less frequently among the women on good diets than among those on poor diets. The infants born to the mothers on poor diets averaged less in weight and were shorter in length, and the majority of the infants born with congenital defects were found in this group. In the paper published in 1949 further studies of the diets of the 216 women were reported. It was found that the women showed little change in food habits in subsequent pregnancies which probably means that in the majority these were the food habits not only during pregnancy but of long-time duration.

In 1944 Balfour reported a study of 20,000 women in the lowest income groups in England and Wales. It was found that supplements of yeast in one group and of vitamins A and D, calcium, phosphorus, and iron in another resulted in significant advantage to the infants as compared with those born to the women receiving no supplements. Stillbirth and neonatal death rates were significantly lower in the groups receiving the supplements.

Also in 1944 Cameron and Graham reported the results of a study at the Glasgow Royal Maternity and Women's Hospital of the food intakes of mothers of prematurely born and stillborn infants and of an equal number of mothers of normal full-term infants. They found the dietary intakes of the mothers with full-term infants superior in all respects and especially so in protein, calcium, and phosphorus.

Toverud, in 1945, reported from Oslo a study of about 1,000 women who, in a program of prenatal care, were given guidance as to their diet during pregnancy. She found a close correlation between the diet, the course of pregnancy, and also the condition of the newborn infant. The stillbirth rate in this supervised group during the years 1939 to 1944 averaged 16 per thousand live births while for the city of Oslo it was 30 per thousand and the neonatal death rate was 11 per thousand compared to 20.

The effects of severe food restrictions in some of the countries of Europe during World War II have been reported by several investigators. In the rationing program of England special attention was given to the diet of pregnant women in the lower income groups because it was known that previous to the war their diet was poorer than that of the average adult. Additional milk, eggs, and vitamin supplements were allowed for all pregnant women. In 1946 Suther-

land reported that a study of stillbirth rates in England and Wales for the years 1928 through 1944 showed a sharp drop after the introduction of rationing and that the drop was most marked in the poorest economic districts. The neonatal death rate also declined but not as much as the stillbirth rate. Baird in Scotland found a similar drop in the stillbirth rate during the war.

Smith, working in Holland where, due to the war, severe famine conditions existed during the winter of 1944 and spring of 1945, found that about 50 per cent of the women suffered from amenorrhea and that this condition disappeared shortly after the return of sufficient food. Birth weights of infants born at full term decreased sharply during the famine months along with a significant drop in birth length. Both birth weight and birth length improved after the end of the starvation period.

Antonov, working in Leningrad during the siege of the city in 1942, found that during the first half of the period the stillbirth rate rose to 5.6 per cent or double the normal figure, the premature births rose to 41.2 per cent, an unusually high figure, and neonatal deaths to 21.2 per cent, also unusually high.

A number of studies of this kind by other workers have shown similar results, leaving no doubt as to the importance of good nutrition during pregnancy. The proper time to begin to improve the diet of the mother is in her own childhood so that she may come to womanhood with her body well developed and at all times in an optimal state of nutrition. Then the diet of pregnancy need differ only in certain details from that to which she has been accustomed.

Nutrition before Birth

Pregnancy is a period of growth and the diet must be relatively rich in all growth-promoting substances. There need be, however, no marked increase in the total energy value of the diet until the third trimester. The gain in weight of the fetus is at first scarcely more than 1 gram per day. By the sixth month it is about 10 grams per day, but about one-half of the weight of the newborn is acquired during the last eight weeks before birth.

Studies of the basal metabolism throughout the gestation period show that it is only in the last three or four months that the metabolism of the fetus and the increased weight of the mother (amounting to about 22 pounds) have any noteworthy effect upon the total energy requirement of the mother. Elevation of the basal metabolism

at term has been reported by various workers as amounting to 15 to 30 per cent. See Tables I(a) and III(a) for the recommended daily allowances for pregnant women and Table XVI(e) for a suitable percentage distribution of the calories.

For the construction of new body tissue there must be available all essential amino acids; hence the quality of the protein of the diet is important. The storage of mineral elements increases as the fetus develops. The tables of recommended allowances show the increases in these nutrients which should be made in the third trimester.

The teeth are all under construction before birth. They begin to form by the third month and at birth all the 20 teeth of the first set are inside the jaw and their crowns almost completely calcified. Their normal development depends not only upon mineral elements (especially calcium and phosphorus), but also upon conditions favorable to the utilization of these elements which are insured by liberal amounts of vitamins A, D, and ascorbic acid. That the demands for vitamin A are higher in pregnancy than in growth was shown by Sherman and F. L. MacLeod who found in studies with animals that "a proportion of vitamin A in the food sufficient to support normal growth and maintain every appearance of good health, for a long time at least, may still be insufficient to meet the added nutritive demands of successful reproduction and lactation."

The thyroid gland is especially active in pregnancy and if the mother has been living on the margin of safety as regards iodine the gland may enlarge in an effort to perform its functions without an adequate supply. In areas where goiter is endemic iodine should be given throughout pregnancy to prevent goiter in the baby as well as in the mother. As pointed out in Chapter 11 the use of iodized table salt is one of the best means of insuring sufficient iodine.

During pregnancy the mother must eliminate the waste products from the unborn child in addition to those from her own body, and it is important that this be facilitated by a relatively large proportion of liquids. At least 2 quarts of fluid should be taken daily. One quart should be milk and of the remainder a considerable part may well be the citrus fruit juices. When fresh milk is not available, milk powder or evaporated milk should take its place. The milk will insure protein of good quality. In addition it is desirable to include lean meat, $\frac{1}{4}$ pound, and an egg daily.

The diet will also need to be more laxative than usual. Liberal

amounts of fresh fruits and green leafy vegetables, with whole wheat bread and bran breakfast foods, are most desirable at this time, not only for laxative effect but for mineral elements and vitamins. Care should be taken in their selection to secure a liberal supply of vitamin A, thiamine, ascorbic acid, and riboflavin. In addition to a well-regulated diet, the prospective mother should spend several hours each day out of doors exposed to bright sunshine. If the locality or the season makes this impossible, she should take at least 2 teaspoons of cod liver oil daily, or if preferred, a cod or halibut liver oil capsule as a source of vitamin D. The diet of the pregnant woman cannot safely be left to chance. Many women at the beginning of pregnancy are in a state of undernutrition and may require a considerable increase in energy-yielding, body-building, and regulating foods.

The dietary essentials may be provided if the following foods are included daily:

One quart of milk (part of this can be canned evaporated or the equivalent in milk powder).

Eight ounces of orange juice plus two or more servings of fresh fruit.

Two to three servings of vegetables to include a dark green leafy vegetable ($\frac{1}{2}$ cup fresh or cooked), a potato, and one other, such as peas, green beans, carrots, or broccoli (fresh, canned, or frozen).

One egg daily.

Four to 5 ounces of meat or fish to include one serving of a glandular meat each week.

One serving of a whole grain or restored cereal and several slices of whole wheat or enriched bread. Wheat germ may be added to cereal as an additional source of thiamine.

Other foods including butter or fortified margarine, more vegetables, fruits (dried or fresh), bread and cereal, etc., to make up the necessary calories.

One to 2 teaspoons of cod liver oil or, if preferred, a cod or halibut liver oil capsule.

The Nutrition of the Nursing Mother

When the baby is born, the demand upon the mother for nourishment does not cease; it merely takes another form and continues to increase with the growth of the child. The secretion of the mammary gland is wonderfully adapted to the needs of the baby. Every well-nourished mother with instruction should be able to nurse her baby.

But it is not to be expected that a mother may entirely overcome bad habits of diet throughout all her previous life in a few days or weeks after lactation has begun. Preparation for lactation begins in pregnancy and adequate nutrition throughout the gestation period should enable a mother to meet more successfully the strain of lactation.

Quantitatively, the demands on the mother grow greater day by day. A baby a week old may need only 16 ounces of milk in 24 hours, but within three months may be taking 28 or 30 ounces. Twenty-eight ounces of milk mean about 532 calories. These must be secured from the food eaten by the mother, or else taken from the fuel reserves of her own body. Oftentimes mothers lose weight during the lactating period or fail to produce milk to full capacity because of insufficient food. See Tables I(a) and III(a) (Appendix) for the recommended daily allowances for lactation and Table XVI(e) for a suitable percentage distribution of the calories.

To furnish the protein represented in the milk there should be added to the mother's diet at least twice as much protein as the protein withdrawn in the milk.

The calcium requirement is increased during lactation to 2 grams. The needs for extra protein and calcium are most efficiently met by the liberal use of milk.

The baby's need of vitamins must also be met at least in part by the mother's milk. Even though vitamin A and riboflavin can be stored, they should be liberal in the diet all the time, since it would be a distinct disadvantage to the mother to give up her reserves. Thiamine and ascorbic acid also need to be plentiful every day, since there will be little or no body store of either to draw upon and the requirement for thiamine in both pregnancy and lactation is high. To meet the infant's need for vitamin D it is now customary to give babies cod liver oil by the end of the second week.

The daily foods for lactation are the same as for pregnancy (see page 454) excepting that milk is increased to $1\frac{1}{2}$ quarts, vegetables and fruits are used more liberally, and larger amounts of bread, cereals, and other foods of the mother's own choice are recommended to raise the calorie intake to the higher level demanded by lactation.

Feeding the Baby

The normal child of a well-nourished mother, although requiring constant and intelligent care, should not be a nutritional problem. Nature provides the ideal nourishment in the secretion of the mam-

mary gland, which in response to the sucking of the child yields nutriment proportional to that demand. The vigorous child thus assures his own supply; the delicate child may be the victim of insufficient food because he cannot "work his way" so well. To-day such infants are helped along by manual stimulation of the gland, whereby milk is furnished the baby and the supply is kept up until greater strength enables him to draw enough for his needs.

The most important considerations for the breast-fed baby are therefore:

(1) A well-nourished mother.

(2) Strength to draw milk as needed or help if strength is inadequate.

(3) Conditions of life which make it possible to digest the food eaten.

(4) Adequate rest, freedom of movement, fresh air and sunshine, to insure the best use of food absorbed.

A well-nourished mother must have not only the food required to maintain herself, but in addition the equivalent of the food material given to the baby as milk every day.

The digestive tract of a baby is very delicate and has a great deal of work to do because of the relatively high food needs of this period of very rapid growth. An upset means loss of food that can ill be spared, and disturbance of the tract itself which may lead to irritability, acute indigestion, or, if long continued, to chronic malnutrition. Regularity of meals is of prime importance. When intervals between meals are neither too short nor too long, the milk will be more uniform in quality, and intervals of rest for the stomach will aid appetite and digestion. A mother (especially with her first child) appreciates the advice of a physician skilled in the care of babies and should have it if possible either from a private physician or from a member of the staff of a baby health station or child welfare clinic. Every day is significant in a little baby's life, and expert supervision makes possible the finest adjustment of the daily program to the needs of the greatest individualist in the world—the baby.

Without adequate rest growth is impossible. The newborn child sleeps the greater part of the 24-hour day. At six months of age, it still sleeps 16 to 18 hours, and at the end of a year, about 14 hours. When not sleeping, the very young baby should lie in a comfortable bed, free to move but not moved by someone else, except when

feeding or change of clothing makes handling necessary. When the child is old enough to sit up, care must be taken to guard against overdoing the new accomplishment. At the least sign of fretting it may be well to lay the baby upon its bed. There is no better place to rest and no more comfortable place to cry.

Fresh air is the best of tonics and the necessity for sunshine has been pointed out in connection with the discussion of vitamin D and rickets in Chapter 15. As an additional safeguard, the routine use of cod liver oil has proven of great advantage to all babies, beginning about the second week of life with a drop or two and increasing the amount very gradually. Plenty of vitamin D thus supplied may mean the difference between good teeth and bad, between a well-coordinated set of joints to promote good posture, and freedom from knock-knees, flat feet, and other hindrances to easy standing and walking; or (for the girl) between a well-developed pelvis and easy maternity or a poorly developed one and perilous motherhood. There is nothing to lose and a chance of much to gain by its use.

Supplementary Foods for the Breast-Fed Baby

In the sixteenth century mothers were advised not to wean their children until they had all their teeth. To-day in the United States it is usual to wean a baby before it is a year old. Often by the seventh or eighth month the baby is strong enough so that the inevitable difference between the best "artificial" diet and mother's milk need not be a serious obstacle to success. A very young baby is in danger of having his digestion upset by any food but his mother's milk. In case of misfortune, we must do the best we can, but it is usually best to give the baby the benefit of his mother's milk through the first six to nine months of his life.

This does not mean, however, that we are to let the baby subsist exclusively on his mother's milk for six to nine months and then abruptly change to other food. Such a course is fraught with peril if not disaster. Preparation for weaning should start early and the baby should be accustomed gradually to the foods which are to be his diet when weaning is fully accomplished. Since babies in the temperate zone, especially if born in the fall, are liable to rickets, it is well to begin giving a few drops of cod liver oil about two weeks after birth. At the age of one month $\frac{1}{4}$ to $\frac{1}{2}$ teaspoon may be given twice a day between two breast feedings, and by the age of three

months this can be increased to a teaspoon twice a day. From this time on the amount can be increased to $1\frac{1}{2}$ teaspoons twice a day so that for the remainder of the first year the child will be receiving between 2 and 3 teaspoons each day. Some physicians advise the use of multiple-vitamin preparations instead of cod liver oil.

Mother's milk should also be supplemented by ascorbic acid since liberal amounts of this vitamin are favorable to the development of the teeth and protect against subacute scurvy. For this purpose a teaspoon of strained orange juice diluted with water or two of tomato juice is most suitable, and may be introduced in the second week, between two breast feedings.

As the next step in training the baby to a mixed diet, a cooked cereal jelly is desirable. A teaspoon or two, cooked very soft, strained, and seasoned lightly with salt, may be given at the time of a morning and evening feeding. The main object at this time is to establish the habit of eating and enjoying cereals. When the habit is well established the quantity can easily be increased to 4 or 5 tablespoons by the seventh month. The canned cereal foods for infants may be used.

By the third to fifth month, $\frac{1}{4}$ of a teaspoon of egg yolk may be given and this can be gradually increased to 1 egg yolk by the eighth month.

A further step in training the baby to other foods may be taken in the fourth to sixth month by adding a little cooked and sifted green vegetable, at a feeding when cereal is not given. Preference should be given to those vegetables rich in iron, such as spinach, peas, or carrots. A teaspoon is sufficient for the first few weeks after vegetables are introduced into the diet, gradually increasing to a tablespoon of sifted pulp.

Fruit pulp may be added to the daily program, beginning with a teaspoon and increasing gradually to 1 or 2 tablespoons. Sometimes the fruit pulp is given as the first solid food instead of cereal depending on what seems to agree best with the baby. It is important that the baby enjoy his food and that it agrees with him.

When several teeth come, a crust of bread may be given at the conclusion of one feeding to start training in mastication. By the time these various steps have been taken, it will be possible to substitute cow's milk for one breast feeding and shortly thereafter to

substitute a second feeding of cow's milk, after which complete weaning should be comparatively easy.

Regularity in the feeding schedule helps to maintain a milk supply of uniform quality, and also assists in keeping the baby's digestive tract in good condition by suitable intervals of rest between meals. As a rule, intervals between meals should be not less than three hours, and after a baby is three months old (if not sooner) may be lengthened to four hours. Cool boiled water should be given between feedings, as the baby's water needs are high. Whatever the schedule decided upon, it should be adhered to as long as it makes for a happy baby.

The night's rest of the mother should be broken as little as possible. Most babies are now trained to sleep from midnight to morning without nursing, and after the age of three months, the last feeding may be given at 10 P.M.

Artificial Feeding of Well Babies

No matter how strong our convictions as to the importance for the baby of breast feeding through the major portion of the first year, we cannot shut our eyes to the fact that circumstances may arise which make the substitution of some other form of nourishment imperative. It behooves us therefore to be prepared to deal intelligently with such emergencies.

In its essence, the problem of planning a diet for a baby is not very different from that of planning a diet for any growing child. There is the same need of an adequate supply of calories; of protein, with growth-sustaining amino acids; of an assortment of mineral elements and vitamins, each suitable in amount for rapid growth; and of a liberal supply of water. The relatively high requirements for mineral elements and vitamins have already been discussed in detail in earlier chapters. And the daily program for the one-year-old child will be found in Chapter 27.

The special problems of artificial feeding in infancy lie chiefly in making the diet sufficiently easy to digest. Any food but mother's milk is a risk in the stomach of the young baby. The selection of foods which will meet all the quantitative requirements, the arrangement of the feeding schedule, the way in which the meals are prepared and fed, in fact the whole daily regime of the baby must have

the most careful consideration in every detail if the venture is to be successful. The younger the baby, the more difficult the task. Whenever any mother's milk is available it should be used, even if it is not enough and has to be supplemented by other food.

The best foundation for the artificially fed baby's diet is pasteurized cow's milk of the best quality or its equivalent of evaporated (unsweetened) milk. An ounce and a half of milk per pound of the baby's weight will furnish the requisite protein and the major portion of the total calories. To this must be added some easily digested carbohydrate food, such as milk sugar, corn syrup, dextrimaltose, or cane sugar. From this the calories needed in addition to those furnished by the milk are derived. Water must be added to the milk and carbohydrate mixture, because without it the food will be too hard for the baby to digest.

The milk-carbohydrate-water mixture must be prepared carefully by measure each day, and divided among the feeding bottles which represent the number of feedings to be given in 24 hours. These bottles must be sterilized before using, and the food mixture should be quickly brought to the boiling point before putting it into the bottles. When the requisite amount of food has been put in, they should be stoppered with sterilized cotton or covered with sterilized caps of glass or rubber and kept cool till needed. At feeding time, one bottle should be quickly warmed to body temperature and fed without delay.

When cow's milk has been thus modified for the sake of ease of digestion and to furnish calories sufficient for the baby's energy requirement, consideration must still be given to the other essentials of the fully adequate diet. The cow's milk should furnish sufficient protein, calcium, and phosphorus, but the iron supply will be too low, and at least by the beginning of the third or fourth month some definite source of iron should be provided. At first this may be some iron-bearing cereal food, specially prepared for infants; a little later egg yolk and green vegetable pulp will serve as additional sources.

Since the ascorbic acid furnished by milk is uncertain, a supplementary source should be supplied about the second week, orange or tomato juice serving admirably for this purpose. The amount is necessarily small at first, but can be increased as the child grows. Vitamin D must also be provided from the outset and cod liver oil is usually the preferred source because it will also furnish liberal

amounts of vitamin A, which if not immediately needed for growth, can be stored in the tissues, thus enhancing their vigor and ability to resist infections of many kinds. Exposure to sunlight is always a desirable part of the daily program, not only for its antirachitic effect, but for other healthful influences. Diluted cow's milk does not furnish sufficient thiamine for the maintenance of a baby's best health; hence some special source of this vitamin should be added. A special cereal with added wheat germ as well as iron is obtainable and can be used for the cereal jelly. Other preparations of thiamine are also available.

There are on the market proprietary infant formulas which have been used widely with success. However, one should consult a pediatrician for advice in the selection of a suitable preparation.

If there should be a tendency to constipation a little prune juice may be mixed with the orange juice, or the amount of thiamine very cautiously increased. The best way to determine whether the total calories are sufficient is by study of the weekly weight record to see whether good progress is made (see Weight-Height-Age Table V, Appendix). If a baby does not gain at a steady rate, a systematic search should be made to find the cause. Every mother should have at least one handbook on child care. Publication No. 8 of the Children's Bureau entitled "Infant Care" listed among the references at the end of this chapter is strongly recommended. Advice from a physician expert in the care of babies or a pediatrician should be secured either privately or at a baby health station or other health center. It pays to take the best possible care to start the baby right and to foster from the beginning those habits which promote health and vigor. The reward will come partly in the present, in a healthy, happy baby which is a delight instead of a worry, but more in the future when to the grown man or woman, the full reward comes in the enjoyment of a vigorous adult life and deferred old age.

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Food Needs of Preschool and Kindergarten Children

Since the beginning of this century there have been real gains in prolonging human life and preventing ill health. This improvement has been brought about by a great extension of the application of modern scientific knowledge to the public health problem. Sanitary science has conquered many infectious diseases and protected food and water supplies and the recent rapid growth of the science of nutrition is revealing the full measure of control which diet exercises over life and health.

To-day we have convincing instances which show that improvements in diet are contributing directly to the prevention of sickness and the extension of efficient living. It will, however, take wide adoption of the modern principles of nutrition and carefully controlled observations covering many years to make an impressive demonstration of the improvement in human life which can be achieved by a good diet consistently eaten from birth to old age. But the conquest of goiter and cretinism, of beriberi and pellagra, of scurvy and rickets, wherever these have been scourges, has demonstrated that an adequate diet is a real factor in public health; and from the nutrition laboratory we have abundant proof that by making adequate diets still better we may produce in successive generations of animals, living in exactly the same environment, a distinctly higher degree of health and vigor.

No child ever had as good a chance of being well born as one entering the world in the twentieth century. Down to the nineteenth century babies seemed born to die, for at least a quarter of them

failed to survive the perilous first year. But to-day in the United States the death rate in the first year of life has dropped to only a small fraction of that reported at the beginning of the century. Now that sanitary science has conquered many children's diseases and made safe the food supply, the application of our present knowledge of nutrition is more important than ever, to insure to these "saved" babies normal growth from birth to maturity and attainment of such physical vigor as shall make their adult years long and fruitful. "Where vitality exists," said Bertrand Russell, "there is pleasure in feeling alive. It makes it easy to take an interest in whatever occurs, and thus promotes objectivity, which is an essential of sanity. Vitality promotes interest in the outside world; it also promotes the power of hard work."

Section 1. THE ONE-YEAR-OLD CHILD

A year-old baby of average size will require from 900 to 1,100 or more calories per day, the precise amount varying according to body weight and amount of activity. The large, vigorous, active child will require more total food than the small, delicate, less strenuous one. The energy requirement from day to day cannot be foretold exactly; the regular weighing of the child week by week, and comparison of his rate of progress with our best normal averages is the best criterion of the adequacy of the food supply. But an approximation of the number of calories required is most useful in planning a good dietary, and such increases or decreases as may be necessary are readily made. Every calorie must be chosen with regard to the growth-promoting substances it can furnish and its effect upon the digestive tract. The evidence that the best foundation for the diet is a quart of milk has been summarized in Chapter 20. This amount of milk insures adequate protein, calcium and some other essential mineral elements, enough of vitamin A and riboflavin for growth, and a fair amount of thiamine, all in a form especially easy to digest. For ascorbic acid it is not wise to depend upon the variable supply in fluid milk, but always to use some outstanding source known to digest well, such as orange juice or tomato juice, making a small quantity a regular part of the diet. Four to 6 tablespoons per day of orange juice are ample as a rule.

Egg yolk is desirable for its value in hemoglobin formation and

its many other growth-promoting qualities including excellent proteins, vitamins A, thiamine, D, and riboflavin, and some calcium.

A little green vegetable pulp should also be included, as a further source of iron and other mineral elements, vitamins A, thiamine, and riboflavin, and for its laxative properties. This should be quickly cooked and put through a coarse sieve and should not exceed 3 or 4 level tablespoons, lest it lead to digestive disturbances, which are often insidious and must therefore be sedulously guarded against. Spinach, asparagus tips, and peas are very suitable, singly or in combination, and carrots, though not green, are notable for their high nutritive value. Many varieties prepared especially for infants and young children are available in small cans.

A cereal food should be given, choosing preferably one which yields iron and thiamine, such as rolled oats or a dark farina or a cereal with added wheat germ or one of the enriched cereals. This can be served regularly twice a day if desired, from $\frac{1}{4}$ to $\frac{1}{3}$ of a cup of the cooked cereal in the morning and another similar portion for supper being usually sufficient. Cooked vegetable or ready-to-eat cereal may be substituted now and then for cooked cereal in the evening meal. A small amount of baked potato is also a desirable food for this age, reinforcing the diet in regard to ascorbic acid, iron, and other mineral elements.

For the sake of stimulating the circulation in the gums and developing the chewing habit, some dry bread or toast is extremely important. A little butter on the bread is permissible, but the $1\frac{1}{4}$ ounces of butter fat in the quart of whole milk make much additional fat at this age undesirable. Generally a little prune pulp or apple pulp, put through a sieve and sweetened with the merest trace of sugar, for the sake of palatability, can be used without making the diet too laxative or too difficult to digest, but should be omitted if there is any doubt as to its good effect. The prepared canned infant foods may also be used.

The diet as outlined above may be used with little change throughout the second year. Cereals may be given unstrained, provided they have been cooked very soft. The milk to drink should never be cold. The quantity of bread may be increased. All the bread should be dry and hard. It fails of its main purpose if soft. The egg yolk may be continued and the white gradually introduced if not already being used. Vegetables should be cooked quickly until soft and put

through a coarse sieve or mashed fine. Those which do not lend themselves to such treatment should be deferred till the child is older. The canned vegetables strained for infants may also be used. As an alternate to cereal for supper, vegetable pulp may be combined with milk in a cream soup and served with small squares of toasted bread.

Selecting from the foods which are regarded as best suited to a child of this age, menus such as the following can be planned.

A DAY'S MENUS FOR A ONE-YEAR-OLD CHILD

7:30 A.M.

Cereal, $\frac{1}{4}$ cup, with $\frac{1}{4}$ cup milk

Milk to drink, $\frac{3}{4}$ cup

Bread, $\frac{1}{2}$ slice, toasted, with $\frac{1}{2}$ tsp. butter or margarine

Orange juice, $\frac{1}{4}$ cup

11:45 A.M.

Potato, baked, $\frac{1}{2}$ medium with 1 tbsp. milk to moisten

Peas, strained, 3 tbsp. with a little milk to moisten

Egg yolk, grated and combined with the liver

Liver, canned, strained, 2 tbsp.

Milk to drink, $\frac{3}{4}$ cup

Bread, $\frac{1}{2}$ slice, toasted

2:30 P.M.

Milk to drink, 1 cup, and bread, $\frac{1}{4}$ slice

5:30 P.M.

Cereal, $\frac{1}{4}$ cup, with $\frac{1}{4}$ cup milk

Prunes, strained, 2 tbsp.

Milk to drink, 1 cup

Bread, $\frac{1}{4}$ slice, toasted, with $\frac{1}{2}$ tsp. butter or margarine

One to $1\frac{1}{2}$ teaspoons of cod liver oil (or equivalent) after breakfast and the same after the midday meal

To see whether or not a diet planned in this way is really adequate we may calculate the contributions of each food item as shown in the dietary on the following page. The recommended daily allowances expressed in shares for a one-year-old child will be found in the Appendix in Table I(c). To find the calorie allowance per unit of body weight one is referred to the tabulation on page 84 in Chapter 4. A suitable weight for a one-year-old child is 11 kilograms (24 pounds) and an allowance of 100 calories per kilogram will mean 1,100 calories for the day. The share values given in Table I(c) for the one-year-old child are as follows: 11.00 shares of calories, 18 shares of protein, 40 shares of calcium, 17 shares of iron, 12

A DAY'S DIETARY FOR A ONE-YEAR-OLD CHILD

Shares Contributed to the Diet

<i>Foods</i>	<i>Measure</i>	<i>Cal- ories</i>	<i>Pro- tein</i>	<i>Cal- cium</i>	<i>Iron</i>	<i>Vita- min A</i>	<i>Thia- mine</i>	<i>Ascorbic Acid</i>	<i>Ribo- flavin</i>
Milk, pasteurized	1 quart	6.66	16.8	46.1	1.8	12.2	7.0	8.5	35.2
Orange juice, fresh	$\frac{1}{4}$ cup	0.27	0.2	0.5	0.5	(0.8)	1.0	13.9	0.6
Prunes, canned, strained	2 tbsp.	0.28	0.1	0.3	1.1	1.3	0.2	0.4	0.2
Potato, baked	$\frac{1}{2}$ medium	0.50	0.6	0.3	1.1	0.1	1.1	3.9	0.5
Peas, canned, strained	3 tbsp.	0.21	0.9	0.3	1.7	1.8	0.9	1.2	0.6
Liver, canned, strained	2 tbsp.	0.30	2.2	0.3	5.3	34.9	0.2	—	12.2
Farina, dark (Wheatena), cooked	$\frac{1}{2}$ cup	0.88	1.7	0.5	2.3	(0)	2.5	0	0.8
Bread, whole wheat	1 $\frac{1}{2}$ slices	1.02	2.0	1.7	2.4	0	2.7	0	1.2
Egg yolk	1 yolk	0.50	1.2	0.9	2.7	3.4	0.8	0	1.3
Butter or margarine	1 tsp.	0.33	0.0	0.0	0	1.0	Trace	0	0.0
Sugar	$\frac{2}{3}$ tsp.	0.11	0	0	0	0	0	0	0
Totals from diet		11.06	25.7	50.9	18.9	55.5	16.4	27.9	52.6
Recommended daily allowances		11.00	18	40	17	12	11	14	19

shares of vitamin A, 11 shares of thiamine, 14 shares of ascorbic acid, and 19 shares of riboflavin.

This diet is adequate in calories, protein, mineral elements, and vitamins, as can be easily seen from the calculation of the dietary. It is interesting to see that the quart of milk is the most significant source of each of the dietary essentials with the exception of iron and ascorbic acid. The addition of 2 or 3 teaspoons of cod liver oil or a multiple-vitamin preparation will furnish adequate vitamin D for most normal children.

The little child's diet must be administered with scrupulous care. Not only is it ministering to immediate needs for growth, but it is also favorably or unfavorably affecting the digestive tract and eating habits. Adequate rest is very important. The daily program should include a morning and an afternoon nap and 12 to 13 hours for the night's sleep. No little child should be up after 7 P.M.

Meals must be regular. This is easy to say but very difficult to accomplish, and a rule too often broken by those who take care of little children. Waiting beyond the regular meal time is likely to bring many undesirable reactions such as irritability, fatigue, loss of appetite, or hurried eating.

The foods should be of the best quality, cautiously seasoned, and prepared and served in a way to commend them to the child. By word and action, respect and enthusiasm for the foods which are desirable for his welfare should be imparted. Always the constructive idea that each food is playing its part in building a healthy, happy child should be kept uppermost.

No child should be pitied because of his simple, wholesome diet. No diet is better than that which adequately supports the rapid growth of the early years, and there should be no suggestion of any other possibility than eating it cheerfully at the proper time. Food for the young child is not an amusement but serious business upon which his whole progress in life largely depends. It is not to be expected that all foods will be equally well received at first. New foods are new lessons. They should not be made too difficult. By giving very small portions at first a ready acceptance of many foods is best built up.

No food between meals should be the usual rule. Nothing is more ruinous to good appetite, good digestion, and good discipline than food at improper times.

Sweets should be rigorously withheld. They pervert the appetite and are likely to disturb digestion. The milk itself furnishes plenty of sugar. Only what is necessary to make apple sauce, junket, or other very simple milk puddings palatable should be used.



(Courtesy of Captain Donald B. MacMillan and the American Museum Journal)

Fig. 120. Me-gis-s'oo and Shoo-e-ging-wah are playing with their pet dogs in the July sun at Etah. In the summer months, on days when the wind is not too strong, Eskimo mothers give their babies sun baths on bear- or deerskins stretched on the ground. Needless to say, the little people like it, and continue to like it until they are quite big boys and girls.

Section 2. THE NURSERY SCHOOL CHILD

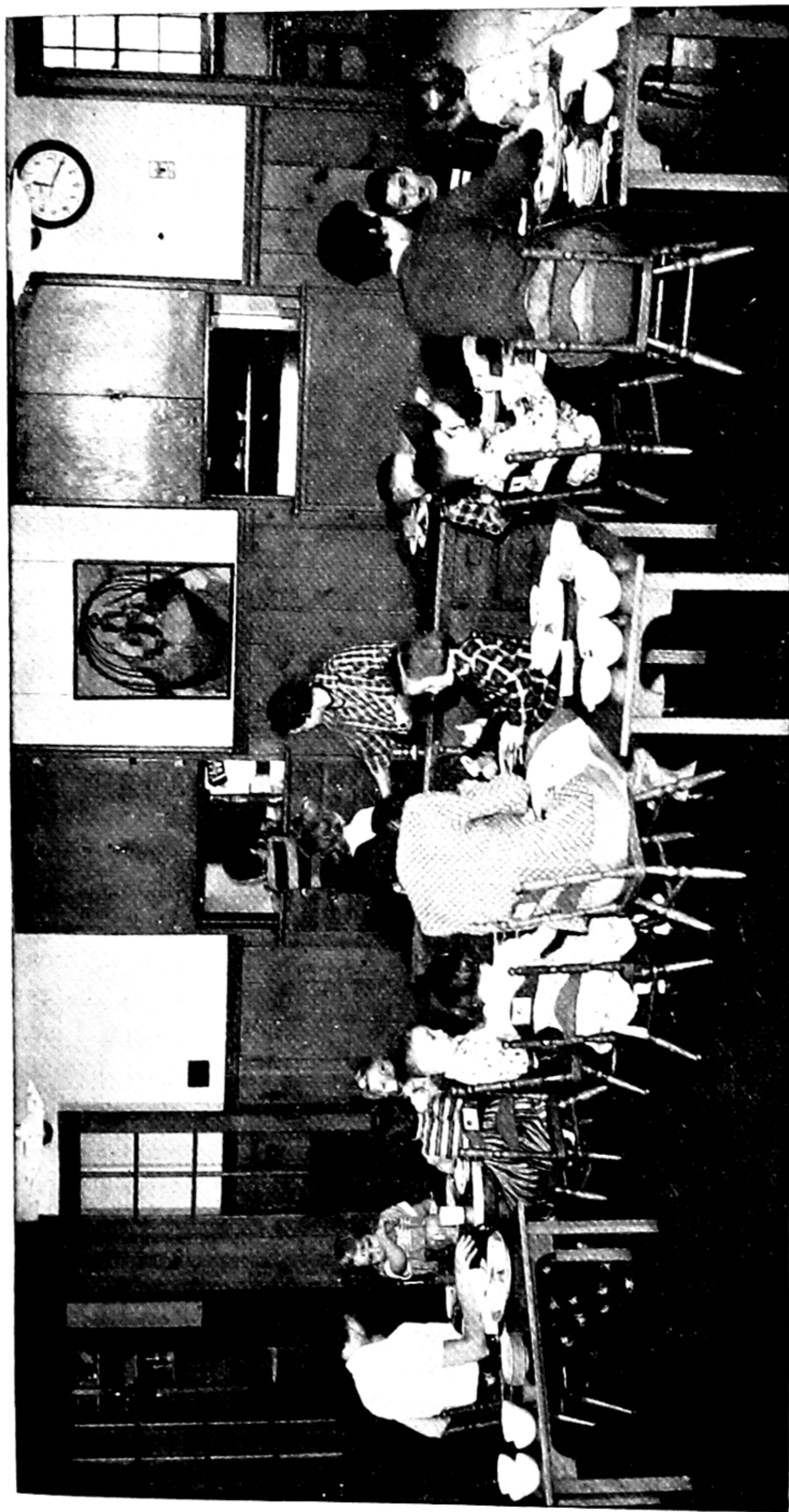
Imitation plays a large part in the little child's life, and it is much easier for him to eat what is given him when others are doing the same. A few children have the opportunity of attending nursery schools and in the future undoubtedly more will have a similar privilege. For such children the preschool period is shortened to a year or so, as sometimes the nursery school admits children under two years of age, though the usual age range is from two to four or five years.

When the children arrive in the morning they should have a drink of water. If they have breakfast early, they should have 3 to 4 ounces of orange or tomato juice between 9:15 and 9:45 A.M., the amount depending on what they may have had at home.

Where the winter season is cloudy, 2 or 3 teaspoons of cod liver oil (or a suitable multiple-vitamin preparation) are a desirable safeguard, giving vitamin A as well as vitamin D. If this is given regularly at home, it may not be needed at the school. If the oil is given it is considered good practice to give it at the end of a meal, because the oil is most easily digested when mixed and diluted with other foodstuffs. There must be at all times the closest coordination between the home and school programs.

The Midday Meal at the Nursery School

The noonday meal, taken at the school, affords an unusual opportunity for training in good eating habits. The food must be selected with the greatest care, since the school's responsibility for the well-being of the children is heavy. It must be apportioned as carefully as possible according to the requirements of the individual child, and yet the group spirit must be preserved. A dietitian expert in the training of children as well as in nutrition is essential to the highest success and should have constant oversight during the meal. The ease with which children two to four years old (and sometimes even younger) can adapt themselves to the food regime of the school is abundant proof of the power of *esprit de corps*. Sitting at their tables with their teachers they eat together in the happiest fashion. Now and then some food seems more of a task than a wee one can accomplish, but helped along by an encouraging word, or perhaps a lift



(Courtesy of Dr. Mary Elizabeth Keister, University of Tennessee)

Fig. 121. The midday meal at the nursery school offers a unique opportunity for training in good food habits.

with the spoon, the goal is won; or a wise teacher quietly lightens the task if in her judgment it is too great for the moment. It is highly important that anyone who supervises the children's meals have training in nutrition as well as in other phases of child care, so that the child's immediate food needs and his education may be properly related to each other.

Day by day the nursery menu must exemplify the best that is known in regard to child feeding. It affords education for parents as well as children. A good program for the dinner will include:

(1) A baked or mashed potato.

(2) A vegetable rich in mineral elements and vitamins, cooked soft and chopped or mashed. Canned "junior" prepared foods may be used. Children of this age can be educated to a considerable range of vegetables, and while a great variety is not essential to their immediate growth, carrots, spinach, and peas being all that one really would need, it is advisable for the convenience of the home and the future ability of the child to widen the range gradually so that the child adjusts himself easily to all wholesome food.

(3) The yolk of an egg. While the yolk is more important than the white for the young child, economic considerations do not justify a school in rejecting the white of an egg. Hence a daily average per child of from one-half to a whole egg seems best under ordinary conditions. The egg can easily be given scrambled or made into a soufflé or a prepared vegetable dish or a simple dessert such as boiled custard (which children seem to prefer to baked), or bread pudding may be made with a boiled custard. Occasionally the egg may be omitted so that it may be included in the home menu. Liver, steamed and put through a food chopper, may be creamed or made into a loaf and served with the vegetables. Fish, such as halibut, or a little chopped lean beef may also serve as an egg substitute now and then, about 1 to 1½ ounces of any one of these being given to each child. Liver is by far the best choice in meats and should be included once a week. Meat must not be allowed to displace milk or vegetables but be so employed as to increase their consumption. For example, a small piece of crisp bacon will frequently result in a child's eating more of his vegetables.

(4) A full cup or a carton (8 ounces) of milk at room temperature. This may be managed more easily by the children if a small

cup is used and refilled. The person in charge has to see to it that each child gets his full share.

(5) A regular portion of dry bread to chew. The quantity cannot be very large or it will take the children longer to get through with their meal than they can endure to sit, even in chairs adapted to their size. Half a slice of whole wheat bread thoroughly toasted will serve the purpose very well. Other breads, untoasted, can be used to fill the quota of calories.

(6) For the sake of establishing the habit so desirable later on of eating a certain amount of fresh uncooked vegetable food, it is permissible to incorporate a very little minced raw vegetable into the diet at this age, using it as a sandwich filling. Carrots and lettuce lend themselves admirably to this use; a little of the carrot top can be chopped in with the carrot itself, and a very little raw apple with the lettuce. The sandwiches are well liked by young children, and in the light of modern knowledge of food values, are an improvement over bread and jelly, jam, or honey. Such use of raw vegetables must not be interpreted as countenancing the indiscriminate use of raw vegetables or fruit at this period. Except as given above, neither is safe for young children. With the exception of orange juice or other mild fruit juice, fruit should generally be cooked, though thoroughly ripe bananas may be cut in small pieces and served with orange juice. The effects of even mild indigestion are insidious and should be most carefully guarded against.

A rather definite pattern for meals helps a child to learn which foods are served together and he forms the habit of eating his vegetables with his egg or meat at the noon meal and his cereal for breakfast. When the appetite is good and there is a desire for more food, giving small amounts of each food on the plate prevents a child from singling out any one food he likes and thus distorting a well-planned diet. A second helping of meat if served alone would, for example, increase the proportion of the protein above a desirable amount when if eaten along with the vegetables it does not change the pattern of the diet.

Cooperation between School and Home

The nursery school child may remain in school till the middle of the afternoon, in which case the interval between the early school

dinner and the evening meal may be over five hours. If this is likely to be the case, the school schedule may include a light afternoon feeding, especially for children under three or four. From 6 to 8 ounces of milk served with a plain, hard, whole wheat cracker makes a good afternoon refreshment, if it does not interfere with the appetite for supper. Here again adjustment between home and nursery school is imperative. If the appetite for supper is interfered with, the afternoon feeding should be omitted or the size of portions decreased till an adjustment is secured.

If the child has only breakfast and supper at home, the nursery school must be responsible for 500 to 700 calories. In one nursery school Graham crackers are always furnished with the dessert, giving not only extra calories for the children who need them, but also something more to chew.

With the child eating in two places, the best diet cannot be assured unless there is continued cooperation between the school and the home. By frequent conferences with the parents the dietitian must learn the home situation in detail and they together must arrange a plan which will insure a unified day's dietary for every child. Such a plan for a week is given on page 475. Obviously, this is built around the noonday meal at school, which must serve the whole group with only such modification for individual cases as comes from changes in quantities of food served, since it would be impossible to cook a different meal for each child.

The home breakfast should consist of a well-cooked cereal, served with milk, a cup of milk to drink, and from one-half to one slice of toast or zwieback or dry bread. When orange juice is given at the nursery school, less needs to be given with the breakfast, and an equal amount of prune or apple pulp may well be substituted. Prunes are valuable where a more laxative diet is needed, and so are cereals made from whole grains.

A very good main dish for supper is a scalloped or creamed vegetable, cottage cheese, a poached egg on toast, milk toast, or cereal and milk; or sometimes a baked potato with another vegetable cooked soft and well mashed, some bread spread lightly with butter or fortified margarine, and a cup of milk to drink.

There may be added, if the child sleeps well after it, a small serving of mild stewed fruit such as apple sauce, stewed pears, or baked banana. Sometimes a Graham cracker or a plain hard molasses

NURSERY SCHOOL MENUS FOR A WEEK (With Suggested Breakfasts and Suppers)

Hour	Monday	Tuesday	Wednesday	Thursday	Friday
Breakfast 7:30 250-320 cal.	Cereal, $\frac{1}{2}$ - $\frac{1}{4}$ cup Milk, 2 oz. Fruit or fruit juice, 3-5 tbsp. Toast, whole wheat or enriched bread, $\frac{1}{2}$ slice Butter, ^b $\frac{1}{2}$ -1 tsp. Milk, 6 oz.	Same	Same	Same	Same
9:15 50 cal.	Orange or tomato juice, 3-4 oz.	Same	Same	Same	Same
Dinner 11:45 450-550 cal.	Beef, 1-1 $\frac{1}{2}$ oz. Mashed potato, 3-5 tbsp. Green beans, 3-5 tbsp. Dry toast, whole wheat or enriched bread, $\frac{1}{2}$ slice Apple sauce, $\frac{1}{4}$ - $\frac{1}{2}$ cup Milk, 8 oz. Cod liver oil, 2 tsp.	Scrambled egg, 1 Mashed potato, 3-5 tbsp. Peas, 3-5 tbsp. Toast, Melba, $\frac{1}{2}$ slice Fruit cup, $\frac{1}{4}$ - $\frac{1}{2}$ cup Milk, 8 oz. Cod liver oil, 2 tsp.	Liver, 1-1 $\frac{1}{2}$ oz. Baked potato, $\frac{1}{2}$ med. Beets, 3-5 tbsp. Lettuce, 1 leaf Toast, whole wheat or enriched bread, $\frac{1}{2}$ slice Chocolate pudding, $\frac{1}{4}$ - $\frac{1}{2}$ cup Milk, 8 oz. Cod liver oil, 2 tsp.	Creamed egg, 1 Mashed potato, 3-5 tbsp. Spinach, ^a 3-5 tbsp. Fresh tomato, 1 slice Toast, whole wheat or enriched bread, $\frac{1}{2}$ slice Fruit gelatin, $\frac{1}{2}$ cup Milk, 8 oz. Cod liver oil, 2 tsp.	Halibut, 1-1 $\frac{1}{2}$ oz. Mashed potato, 3-5 tbsp. Carrots, 2-3 tbsp. Peas, 2-3 tbsp. Toast, whole wheat or enriched bread, $\frac{1}{2}$ slice Orange blanc mange, $\frac{1}{2}$ cup Milk, 8 oz. Cod liver oil, 2 tsp.
2:00-2:30 100-175 cal.	Milk, 6-8 oz. Graham crackers, 1-2 small	Same	Same	Same	Same
Supper 5:30-6:30 325-400 cal.	Dry cereal, $\frac{1}{2}$ cup, with banana, $\frac{1}{2}$ Toast, whole wheat or enriched bread, $\frac{1}{2}$ slice Butter, ^b $\frac{1}{2}$ -1 tsp. Custard, $\frac{1}{2}$ - $\frac{1}{2}$ cup Milk, 6 oz.	Scalloped tomato, $\frac{1}{2}$ cup Croutons (1 slice bread) Apple sauce, $\frac{1}{2}$ - $\frac{1}{2}$ cup Cookie, 1 small Milk, 6 oz.	Creamed vegetables, $\frac{1}{2}$ cup Toast, whole wheat or enriched bread, $\frac{1}{2}$ slice Butter, ^b $\frac{1}{2}$ -1 tsp. Stewed fruit, 2-4 tbsp. Milk, 6 oz.	Cottage cheese sand- wich, 1 slice thin Date sandwich, 1 slice thin Strawberry junket, $\frac{1}{2}$ cup Milk, 6 oz.	Poached egg, 1 Toast, whole wheat or enriched bread, $\frac{1}{2}$ slice Butter, ^b $\frac{1}{2}$ -1 tsp. Farina pudding, $\frac{1}{2}$ cup Stewed apricots, 2-4 tbsp. Milk, 6 oz.

^a Or other cooked green vegetable such as broccoli or kale. ^b Or fortified margarine.

Courtesy of Dr. Marie M. O'Donahoe

cookie will prove less disturbing at night. If a child is very restless at night on such a good regime, it would be advisable to see if increasing thiamine, by giving some rich source such as wheat germ or a concentrate such as an extract of wheat germ or yeast, will improve digestion and result in quieter, more restful sleep.

Menus for one day for a three-year-old child, whether attending nursery school or not, might be as follows:

A DAY'S MENUS FOR A THREE-YEAR-OLD CHILD

Breakfast

Orange juice, $\frac{3}{8}$ cup. ^a
 Rolled oats, $\frac{1}{2}$ cup
 Milk, 1 cup (for cereal and to drink)
 Toast, whole wheat, $\frac{1}{2}$ slice
 Butter or margarine, $\frac{1}{2}$ tsp.
 Cod liver oil, 2 tsp. (or equivalent)

2:30 p.m.

Milk, $\frac{3}{4}$ cup
 Crackers, whole wheat,
 2 small

Dinner

Potato, baked, mashed, 1 small
 Carrots, cooked and chopped, $\frac{1}{3}$ cup
 Toast, whole wheat, $\frac{1}{2}$ slice, dry
 Butter or margarine, $\frac{1}{2}$ tbsp., for
 vegetables
 Banana, sliced, $\frac{1}{2}$ medium
 Milk, 1 cup (for banana and to drink)

Supper

Egg, soft-cooked, 1
 Spinach, cooked and
 chopped, $\frac{1}{3}$ cup
 Bread, whole wheat,
 $\frac{1}{2}$ slice
 Butter or margarine,
 1 tsp.
 Prunes (cooked with
 $\frac{1}{2}$ tsp. sugar), 2 large
 Milk, 1 cup

^a If preferred, this can be given as a mid-morning feeding.

It is always desirable to compare the nutritive value of the foods included in the menu with the suggested recommended allowances of specific nutrients. For these calculations and comparisons see the following page.

It will be noted that this selection of common food materials allows a good margin of safety, more than meeting the standards set for each nutrient. With 2 or 3 teaspoons of cod liver oil added for vitamin D, it represents our best present knowledge of how to safeguard the diet of the young child.

Suitable percentage distributions of calories in diets for children of this age will be found in Table XVI(a) (Appendix).

A DAY'S DIETARY FOR A THREE-YEAR-OLD CHILD

		Shares Contributed to the Diet							
<i>Foods</i>	<i>Measure</i>	<i>Cal- ories</i>	<i>Pro- tein</i>	<i>Cal- cium</i>	<i>Iron</i>	<i>Vita- min A</i>	<i>Thia- mine</i>	<i>Ascorbic Acid</i>	<i>Ribo- flavin</i>
Milk, pasteurized	1 quart	6.66	16.8	46.1	1.8	12.2	7.0	8.5	35.2
Prunes, cooked	2 large	0.50	0.2	0.4	1.9	2.3	0.2	0.1	0.6
Orange juice, fresh	$\frac{3}{4}$ cup	0.41	0.4	0.7	0.7	(1.1)	1.5	20.8	0.9
Banana	$\frac{1}{2}$ medium	0.50	0.4	0.2	0.9	1.6	0.5	2.4	0.6
Potato, baked	1 small	0.75	0.9	0.4	1.6	0.1	1.7	5.8	0.8
Carrots, cooked	$\frac{1}{4}$ cup	0.15	0.1	0.5	0.8	38.7	0.5	0.9	0.5
Spinach, cooked	$\frac{1}{4}$ cup	0.15	0.9	*	3.2	45.3	0.9	7.7	2.4
Bread, whole wheat	1 $\frac{1}{2}$ slices	1.02	2.0	1.7	2.4	0	2.7	0	1.2
Crackers, whole wheat	2 small	0.40	0.4	0.1	0.5	(0)	0.6	0	0.2
Rolled oats, cooked	$\frac{1}{2}$ cup	0.74	1.4	0.4	2.3	(0)	2.2	(0)	0.5
Egg, cooked	1 egg	0.75	3.0	1.0	3.4	3.5	0.8	0	2.6
Butter or margarine	1 tbsp.	1.00	0.0	0.1	0	3.0	Trace	0	0.0
Sugar	$\frac{1}{2}$ tsp.	0.08	0	0	0	0	0	0	0
Totals from diet		13.11	26.5	51.6	19.5	107.8	18.6	46.2	45.5
Recommended daily allowances		13.00	22	40	19	14	14	17	21

* Not available.

Section 3. THE KINDERGARTEN CHILD

The child who does not enter a nursery school at the age of two or three years may begin his school experience at the age of four or five in kindergarten. He will have less feeding at school than the nursery school child, but there will nevertheless be certain adjustments necessary when he starts on his school career. Breakfast may have to come earlier and dinner later, and a mid-morning school feeding may become a practical necessity if he is not to be tired out before reaching home at midday. The morning hours cannot be spent in the open sunshine, and plans must be made to secure a good sun bath every day that the sun shines. There is danger of hurrying breakfast and eating an insufficient quantity of food, hence the morning program must be arranged to allow for leisurely eating of the proper amount of breakfast and a bowel movement afterward—no mean achievement for a busy mother and a child sure to be slow when anyone especially wants him to be quick.

The breakfast should continue to consist of orange juice or other fruit juice (stewed prunes or apple sauce occasionally if preferred), well-cooked cereal, toast or other hard bread, and from 1 to 2 cups of milk, part on the cereal and part to drink. Shredded wheat or zwieback with warm milk poured over it may be used now and then instead of oatmeal or dark farina. In either case the child has a warm wholesome breakfast.

For the mid-morning feeding milk as a rule is the most desirable food. The cupful taken then helps to distribute the day's quart advantageously, and the drinking of milk in school tends to reinforce the idea that milk is important. Furthermore, milk is easy to serve and easy to digest. A hard whole wheat or Graham cracker will make it digest more quickly. The mid-morning feeding should always be so timed that the interval between it and dinner is longer than the interval between it and breakfast—nearer nine o'clock than ten.

The dinner should come as soon after the school session as is practicable and should be the most substantial meal of the day. Such dinners as have been outlined for the nursery school children are suitable for kindergartners too.

The evening meal should frequently have as the main dish cereal, toast, or bread with milk, using perhaps rice or some other cereal not served for breakfast. Some of the ready-to-eat cereals with plenty

of milk are excellent for supper. A creamed vegetable on toast with a strip of bacon may be served as an alternative to the cereal supper or a baked potato with some other vegetable.

A dessert of stewed fruit, junket, or other simple pudding may be supplemented by Graham crackers or a plain hard cookie. If the milk is not used for the main dish it should be served as a beverage.

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Food Needs of School Children

How much is a child worth? This challenging question is not an easy one to answer in times like ours. So many factors have to be considered in this age, such as the highly specialized professional services, as well as the many pairs of hands, trained and untrained, which it now takes to carry on the simplest routine tasks around the home and even to make ordinary repairs. A mother has always had to assume a "do-it-yourself" philosophy and her varied services are inestimable in cash value. The success or failure of her efforts are quickly judged by the child who makes his appearance on the first day of school. Does he look happy? Is he alert and receptive? Does he seem to have that superabundance of health which we often describe as robust? Does he seem to have that all-round physical stamina that every school child must have to carry on successfully?

More attention to the health of the preschool and kindergarten child will cut down many of the handicaps which to-day are found among elementary school children. Physical defects should have been as far as possible removed and good health habits already established when the six-year-old enters the primary school. But he cannot now be safely left to guide himself. He has covered only about one-fourth of his period of growth, and good habits are by no means fixed. Furthermore, he is just approaching the years in which inculcation of the reasons for health habits and respect for the laws of hygiene should be a consistent part of his education, both at home and at school. "We strike at one of the roots of physical unfitness when we begin the teaching of food selection to all children, regardless of whether they appear to be undernourished or not. No immediate striking gain in weight is the objective of such teaching. What we want is to rear children who are intelligent as to the role which

food plays in their lives, who are aware of their own responsibility in regard to food selection, and are imbued with a determination to make their daily food a factor contributing to health and not working against it, even though results cannot be measured from day to day nor from week to week—only from month to month or year to year. To this end they must have, (1) the habit of eating certain foods which in large measure insure an adequate diet, (2) sufficient knowledge of the part played by individual foods to make up for themselves suitable combinations for meals, (3) such knowledge of their own food requirements as will enable them to satisfy their needs at a table provided for persons with varying requirements, (4) such ideas of the relation of nutritive value to cost of food as will enable them to be thrifty in meeting their body needs.”¹

Section 1. ELEMENTARY SCHOOL CHILDREN

By the time a child is ready to enter the elementary school he should be eating a diet in which milk, eggs, cereals, vegetables in considerable variety, fruits, especially orange juice, whole wheat or enriched bread, and butter are the chief items. All foods should be cooked as simply as possible. A glass of milk at each meal and a cup of it in soup or dessert will generally take care of the daily quart satisfactorily. No tea or coffee should be permitted. A very little cocoa may be used to flavor warm milk, and often a little malted milk or other powdered products will serve for flavor.

Raw vegetables should be finely cut and used in small quantities until the habit of thoroughly chewing them is established. They may be seasoned with a little fruit juice, but not with the salad dressings commonly used by adults. Fat is best used as a spread for bread, rather than in cooking. Whole milk is better to use over cereals and puddings than cream. One or two Graham crackers or plain hard cookies may be used at the end of a meal in preference to soft frosted cake.

Training Children to Eat

Regularity and simplicity are the great watchwords for the diet of the elementary school child. More and more he will take an

¹ *Health Education Report of the Joint Committee on Health Problems in Education*, second revision, page 52 (1941).

interest in his own food, and more and more opportunity will come to teach respect for all good food because of what it can accomplish for the body. Talk about personal likes and dislikes should be discouraged. The idea that one can get over distaste for food which one knows to be wholesome by repeated efforts to eat small portions should be substituted for any discussion of dislikes. Minor changes in the food often help the child in such an endeavor. A little difference in appearance, flavor, or texture may mean more than an adult is aware of. Grownups make many such adjustments for themselves at the table. Why do pepper and salt shakers appear there, save for this very purpose? "Some like it hot, some like it cold," and which way they have it may be immaterial. It is a wise parent that knows when to insist! Spinach and potato together may be easier to eat than spinach alone. A little more salt or a few grains of brown sugar may make the oatmeal seem like a different food. Remember Dickens' kitten pies—whatever the kind of meat, "it's flavorin' as does it!" Fair substitutes may often be allowed when they do not work injustice to anyone else. If a child prefers shredded wheat to oatmeal may he not have it, since no work is involved in preparing it and the two foods are nutritionally interchangeable? Eventually, he should learn to eat both, but tastes and ideas change and if he is eating according to his own nutritional needs we should not at this time put too much emphasis on variety.

Anyone responsible for feeding a child should be familiar with some of the striking effects of food upon health and growth such as have been referred to in the preceding chapters, and these should be used to put the choice of food upon a higher plane than mere fancy. The demonstration of the effect of food upon the growth and health of animal pets gives a real incentive to eat what one needs regardless of whether it seems most attractive at the moment, and no attitude is more valuable for future health.

In order to fit properly into the family routine every child should be expected to taste any food which it is important for him to eat, every time it is served, but the quantity insisted upon should not be too large if it is difficult for him to take. Frequent repetition under favorable circumstances is much more likely to be successful than a forced overdose. Other habits are established only by patient repetition, and one should not expect food habits to be any exception.

Helping mother in the kitchen with the simple preparation of food may develop a real appetite for tasting and enjoying the final product. There are many constructive things for little hands to do in the kitchen and a wise parent will find them.

General Plan of Meals

The primary school child's energy needs are high but his digestive tract still needs to be carefully safeguarded. Breakfast must be ample but very simple and not eaten too hurriedly. No child starts the day well who has not gone to bed early (before 7:30 P.M.) and had a full night's sleep. A good rest will give him a good appetite for breakfast. Fruit, a warm cereal with milk, milk to drink (not chilled) and toast to chew make a breakfast adequate as to food value and easy to digest. The warm cereal dish may consist of a cooked cereal with cold milk, or a ready-to-eat cereal with warm milk. Care must be taken to have breakfast at the regular time on Saturdays and Sundays as well as school days, and also meals of the same general character should be served. Every day is growing day for a child and whatever food program is important to-day is equally important tomorrow. By this time, if preferred, orange juice can give place to the whole orange, prune pulp to whole stewed prunes, and apple sauce to raw apples or pears, provided they are perfectly ripe. Other mild fresh fruits in season can also be used for breakfast.

School conditions will now affect the time and character of the midday meal. It may be eaten at home or at the school. There should always be one hot dish available, since warm food promotes the circulation, relieves fatigue, and makes the afternoon session easier. Cocoa made with milk or a nutritious milk and vegetable soup with bread and butter (or sandwich) and fruit will make a wholesome noonday meal. When the children can go home for lunch, a potato, another cooked vegetable, an egg, or a little meat, a small portion of some raw vegetable, such as lettuce, tomatoes, cabbage, or carrots, a glass of milk to drink, and a simple dessert of stewed fruit or a milk pudding make a suitable meal. All the foods should be simply cooked, for the child must go back to school to use his brain efficiently, and a meal difficult to digest must not interfere in any way. The delicate child will benefit from a short rest flat

on his back before his dinner; the very active one who wants to eat and run to his play should be kept at the table for at least 20 or 30 minutes so that he will not be tempted to bolt his food.

The evening meal must be simple, since bedtime is not far away. A creamed vegetable soup with toast or crackers, a cooked vegetable and bacon on toast, a soft-cooked egg or chopped meat with a baked potato and one other vegetable, milk toast, cereal and milk are examples of suitable hot dishes. There should be milk to drink, bread and butter with stewed fruit, or a simple pudding for dessert.

To illustrate the selection of food for a child within this age range, we may plan a day's menus for an eight-year-old child requiring 2,000 calories as follows:

A DAY'S MENUS FOR AN EIGHT-YEAR-OLD CHILD

<i>Breakfast</i>	<i>Luncheon</i>	<i>After School</i>
Orange	Scrambled egg on toast	Milk and Graham crack-
Farina, dark, with	(enriched bread)	ers
milk	Carrot strips on fresh	<i>Dinner</i>
Toast, whole wheat,	lettuce	Hamburg steak with
with butter or forti-	Bread, enriched, with	gravy
fied margarine	butter or margarine	Potato, baked
Milk to drink	Milk to drink	Buttered peas
		Bread, whole wheat
		Baked apple
		Milk to drink

How this plan will meet the needs of the child is shown by the calculations on the following page.

It is now easy to see that requirements for protein and mineral constituents are well met when the calories are selected with regard to their ability to furnish these essentials. It is also easy to see how difficult it would be to meet the calcium needs of a rapidly growing child without a liberal amount of milk, since the contributions of the other foods are so insignificant in comparison.

The dietary furnishes 76 shares of vitamin A, of which milk, carrots, egg, and butter make the chief contributions. This would appear more than ample to meet the needs of growth at this age, but since the dietary may not always include vegetables as rich in this vitamin as carrots, the addition of a fish liver oil may be regarded as valuable to increase the body reserves of vitamin A and at the same time insure plenty of vitamin D.

A DAY'S DIETARY FOR AN EIGHT-YEAR-OLD CHILD

		Shares Contributed to the Diet							
<i>Foods</i>	<i>Measure</i>	<i>Cal- ories</i>	<i>Pro- tein</i>	<i>Cal- cium</i>	<i>Iron</i>	<i>Vita- min A</i>	<i>Thia- mine</i>	<i>Ascorbic Acid</i>	<i>Ribo- flavin</i>
Milk, pasteurized	1 quart	6.66	16.8	46.1	1.8	12.2	7.0	8.5	35.2
Orange	1 medium	0.70	0.7	2.0	1.6	2.2	2.4	35.0	1.6
Apple	1 small	0.58	0.1	0.2	0.8	0.6	0.8	2.1	0.6
Potatoes, baked	2 small	1.50	1.8	0.8	3.2	0.1	3.3	11.6	1.5
Carrot, raw	25 thin strips	0.25	0.4	0.9	1.3	45.8	0.7	1.5	0.7
Peas, cooked	$\frac{1}{2}$ cup	0.37	1.3	0.5	2.6	2.5	2.7	3.4	1.5
Lettuce	3 leaves	0.09	0.4	0.5	0.8	1.5	0.9	2.7	0.7
Farina, dark, cooked	$\frac{1}{2}$ cup	0.88	1.7	0.5	2.3	(0)	2.5	0	0.8
Bread, whole wheat	2 slices	1.36	2.6	2.2	3.2	0	3.6	0	1.6
Bread, white, enriched	2 slices	1.26	2.0	1.4	2.2	0	2.4	0	1.6
Crackers, Graham	2 large	0.80	0.8	0.2	1.0	(0)	1.3	0	0.5
Flour, white, enriched	$\frac{1}{2}$ tbsp.	0.13	0.2	0.0	0.3	0	0.3	0	0.2
Beef, round, lean	3 oz.	1.38	9.0	0.6	7.2	0.3	2.4	0	3.6
Egg	1 egg	0.75	3.0	1.0	3.4	3.5	0.8	0	2.6
Butter or margarine	2 $\frac{1}{2}$ tbsp.	2.50	0.1	0.3	0	7.5	Trace	0	0.1
Sugar	3 tbsp.	1.50	0	0	0	0	0	0	0
Totals from diet		20.71	40.9	57.2	31.7	76.2	31.1	64.8	52.8
Recommended daily allowances		20.00	30	40	26	22	20	26	30



*(Courtesy of Home Economics Research Branch,
Agricultural Research Service, USDA)*

Fig. 122. Three Eight-Year-Old Girls Showing How Children of the Same Age May Differ Markedly in Body Build

The choice of whole grain or enriched cereals and a vegetable (peas) known to be more than usually rich in thiamine to supplement the milk and the orange results in a total of 31 shares, which is ample even for an active child of this age. The value of milk for riboflavin is better appreciated by seeing that it furnishes about three-fourths of the total amount in the diet and 5 shares more than the recommended daily allowance. The value of the orange as a source of ascorbic acid is quite apparent, as it provides more than half of the total number of shares, and more than meets the standard set without taking account of any other food. The regular use of specific foods for special purposes, as in this instance, greatly simplifies the task of providing adequate diets.

In establishing recommended allowances in shares, one is referred to Tables I(a) and I(c) in the Appendix. Children of the same age vary greatly in weight as will be observed in Fig. 122 which shows three girls eight years of age, each of whom is normal but quite different in height and weight from the others. Knowing the weight, calories for a particular child can be calculated by referring to the calorie allowances per unit of weight given in the tabulation on page 84 in Chapter 4. If one then refers to Table I(c) in the Appendix the allowances in shares for the other essential nutrients corresponding to the calculated calorie allowance will be found. If the calories correspond to those in the table for an older child, one should use the allowances for essential nutrients for the older child just as one would have to get a larger size coat for a child above the average weight for height.

For suitable distributions of calories in the diets of elementary school children see Table XVI(b) (Appendix).

Section 2. SECONDARY SCHOOL CHILDREN

By the time a boy or girl is twelve years old, the upper elementary or junior high school will usually have been reached, and the period of adolescence will have begun. In this period, lasting about ten years, there is a gradual transition from childhood to maturity. Growth, which has been proceeding with a weight increase averaging between 5 and 6 pounds a year, is accelerated about the eleventh year in girls and the thirteenth in boys, as will be observed in Fig. 123. For comparison one may also be interested in looking at the

Weight-Height-Age Table for Boys and Girls of School Age given in Table VII of the Appendix.

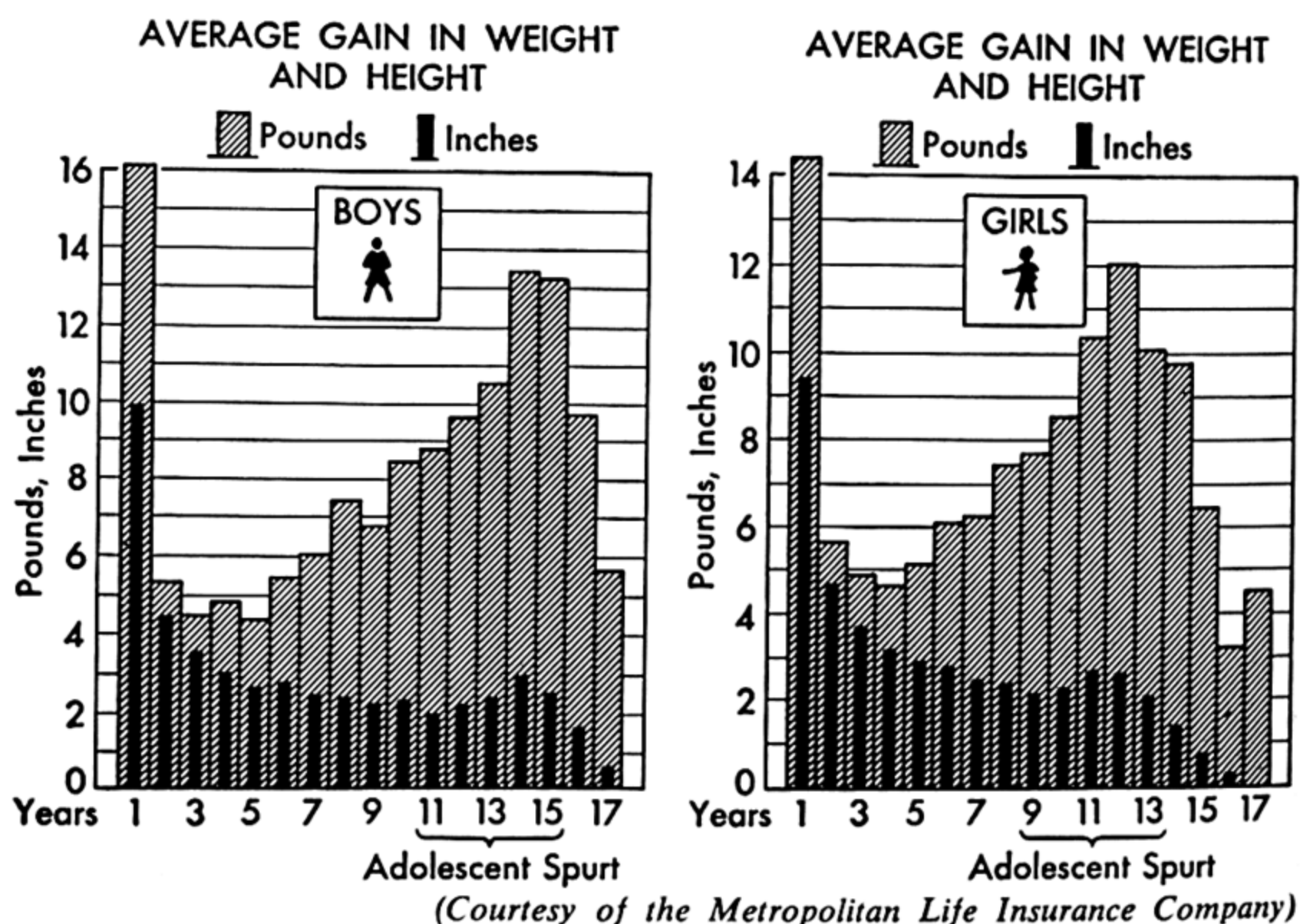


Fig. 123. Growth Charts for Boys and Girls

In most of the years between six and seventeen the average growth in height of boys and girls is about 2 inches and in the years of greatest growth about 3 inches, though some boys grow 4 or 5 inches in the year of greatest growth. For the whole period from twelve to eighteen years in girls and boys, the food requirements will be much higher than for adults of corresponding size, and emphasis must be put upon a diet which is capable of promoting the best possible growth. In nutritive quality it should be the equal of that for the younger children, and in quantity it will resemble the diets of toilers, such as farm laborers and stone workers. A good distribution of calories in diets for high school boys and girls will be found in Table XVI (c).

It is important that regularity of meals and the habit of eating plain wholesome food be maintained throughout the growing period. One who is under the necessity of consuming 1,000 to 1,500 calories per meal has occasion to give thought to the concentration of the diet, to insure a sufficiency without undue strain upon the digestive

tract on the one hand or "meals at all hours" on the other. In *Seventeen*, Booth Tarkington well depicted the tendency of the voracious age, in Jane, who is continually eating bread and apple sauce and brown sugar. That is not the best way, however, to meet the high food needs of adolescence. With care, the needed calories can be given for the most part in three regular meals, though opportunity to secure a little extra nourishment in the form of bread and butter, or crackers and milk, is often necessary.

A quart of milk a day should be allowed for each boy and girl, and if this is all taken as a beverage more may be used in cooking. The use of foods from the cereal grains should be encouraged; various forms of bread are most useful, especially those of whole grains reinforced with nuts, dates, raisins, etc. Sweet dried fruits (dates, raisins, and figs) with their high fuel and mineral values admirably supplement fresh fruits, and can be used in many ways. Vegetables whose fuel value is low can be cooked with more butter or with white sauce, and salads can now have the cream or oil dressings which add so many calories in a small volume, provided they are not too highly seasoned. Meat is an acceptable addition to the diet by reason of its appetizing properties and its power of giving the "staying" qualities which are such a desideratum at this age. It should be borne in mind that although meat furnishes protein of high quality, it needs supplementing always by milk and vegetables to give the calcium and certain vitamins in which it is low.

Some Considerations Influencing Choice of Food

The kinds of food habits which boys and girls form as they come to make their own choices are the food habits they tend to carry over into adult life. A taste for plain, wholesome food, simply prepared, is a most valuable nutritional safeguard, and should be fostered in every possible way. If the appetite is not "up to" milk, vegetables, and fruits accompanied by good bread and butter, something is wrong with the mode of life and the remedy is not highly seasoned food, such as "hot dogs," pickles, mince pie, or ice cream soda. Often what is most needed is more sleep, less excitement, and fewer temptations to make eating "the great indoor sport."

Boys are more likely than girls to accept without protest a simple regime, provided it really gives them a diet which appeases their chronic hunger. Quantity is the great consideration. Girls, whose

urge to eat is not so compelling, pay more attention to the esthetic aspects of their diet. This is somewhat true even of girls leading active lives and taking their recreation in the form of outdoor sports. It will cost just as much to feed a girl as a boy although she eats a third less calories, because the calories she does eat must carry nearly as much building and regulatory material as his, and her normal food intake is less sustained by the demand of hunger and more through the appeal which the food makes to the eye.

Many of the dietary problems presented by girls can be met ideally only as physical perfection can be made to seem worth working for. Not yet do women as a class take pride in physical fitness. A girl must see advantages in health in order to be willing to strive for it. Where thinness is admired she will work for thinness; where fatness is regarded as a mark of beauty, she will do her best to be fat. Her desire for beauty and praise far outruns her desire for food, and it will only be as higher ideals are developed that she will consciously endeavor to live hygienically. Her diet should be chosen with regard to its appearance and flavor, with emphasis upon growth-promoting factors. Plenty of fruit and vegetables and eggs, along with a quart of milk a day, may well constitute a large part of the dietary at this time. Cakes, pies, fancy desserts, and candy cut down the proportion of mineral elements and vitamins and are likely to disturb digestion and increase the calories. For the sake of good teeth and hair and a clear complexion they should be minimized. There is no better habit than that of persistently choosing simply prepared foods of delicate flavor. Everyone should learn to curb in himself any tendency to highly flavored foods, whether sweets, pickles, pepper, catsup, or other so-called food adjuncts, not because of any immediate harm but because wise food habits acquired and maintained are the surest and easiest road to good nutrition so far as choice of food is a factor, while the habit of demanding highly seasoned food is bound to grow and make the more wholesome plain foods distasteful.

The best regulator of appetite is plenty of fresh air and sunshine, with long hours of sleep at night. Regular meals should be insisted upon, even if little food be eaten, and if a girl is underweight, more rest should be taken to cut down energy expenditure and make it balance food intake.

The foods which should be chosen first are those called protective

because they are rich in mineral elements and vitamins. It is important for every high school boy and girl to know these "must" foods which should appear in the dietary every day, so that they may acquire the habit of choosing their foods accordingly. Some simple rules like the following which can be used by both girls and boys will be helpful.

1 quart milk

$\frac{1}{2}$ to $\frac{3}{4}$ cup orange, grapefruit, or tomato juice or their equivalent in fresh fruit

$\frac{1}{2}$ to $\frac{3}{4}$ cup of green or yellow vegetable

1 potato

1 egg daily or at least 3 or 4 per week

4 to 5 ounces of meat, poultry, or fish

4 to 6 slices of whole wheat or enriched bread or equivalent

Other foods such as cereals, fats, sweets, and additional vegetables and fruits to meet the calorie requirement

It will be noted that the only difference between these rules and those given for the adult is in the amount of milk. Every boy and girl should have a full quart of milk each day until they have stopped growing. With these simple rules in mind, then, a day's menus for a high school boy actively engaged in athletics might be similar to the menus shown below.

It will be noted that the menus allow for three glasses of milk for drinking, the fourth glass to be used for cereal and dessert. The breakfast includes the fruit juice, eggs, and cereal; and the dinner, the green vegetable, potato, and meat. The bread is distributed throughout the three meals and the other foods provide the extra calories needed.

A DAY'S MENUS FOR A HIGH SCHOOL BOY

<i>Breakfast</i>	<i>Luncheon</i>	<i>Dinner</i>
Orange juice	Hash (meat and potato)	Meat with gravy
Oatmeal with dates and milk	Peas	Potatoes
Toast, whole wheat, with butter or mar- garine	Cabbage, raw, shredded	String beans
Eggs	Bread, whole wheat, with butter or margarine	Lettuce with mayonnaise dressing
Bacon	Gingerbread	Rolls (of enriched flour) with butter or mar- garine
Milk to drink	Milk to drink	Apple Betty with milk and sugar
		Graham crackers
		Milk to drink

The test of any such plan is the nutritive value of a dietary based upon it. In the one which follows worked out in detail for a boy requiring 5,000 calories per day, we have evidence that there has been adequate provision of building materials as well as calories, and we have every reason to believe that the vitamin supply is ample. Nevertheless, during this period of rapid growth, the inclusion of a fish liver oil capsule in the winter season may be regarded as an additional safeguard, not only because it furnishes vitamin D, but because it also adds to the reserves of vitamin A. The same precaution should be taken for the high school girl.

The calculations show how milk, which has become a less prominent source of calories, is still the mainstay for calcium. The dietary yields a very liberal amount of iron, over one-half of which comes from the cereal grains and fruits and vegetables, and about one-fifth from the eggs and molasses. There are fifty-two shares of vitamin A, very valuable at a time of rapid development of all parts of the body, more than half of which are contributed by milk, butter, and eggs, the rest mainly from the vegetables. Thiamine is also liberally provided, to meet the extra demands of great activity as well as rapid growth. The whole wheat bread and oatmeal furnish one-fourth of the total amount, peas alone almost one-tenth, and milk and potatoes together about one-fifth. The total amount is considerably above the standard which allows a wide margin of safety for growth. The orange juice is the outstanding source of ascorbic acid, furnishing the total amount needed, and the potatoes and cabbage together contribute considerably more than the recommended allowance and insure adequacy in respect to this vitamin. As this is probably several times the minimum necessary to prevent scurvy, it should afford good tooth protection. Almost half of the total riboflavin is furnished by milk. Provision for vitamin D must be made by much outdoor exposure to the sun in summer, and by some special source, as vitamin D milk or cod liver oil or its equivalent, in winter.

The problem of feeding a high school girl is quite unlike that of providing for a boy of the same age. In the first place, the difference in energy needs is usually quite marked. The activities of high school girls tend to be of a less strenuous type and engaged in for shorter periods of time than those of boys. Consequently, a girl may need a total of 2,400 calories per day at the age when a boy would eat 4,000 or 5,000.

In spite of a lower calorie requirement, the growing girl needs a

A DAY'S DIETARY FOR A BOY REQUIRING 5,000 CALORIES

Shares Contributed to the Diet

<i>Foods</i>	<i>Measure</i>	<i>Cal- ories</i>	<i>Pro- tein</i>	<i>Cal- cium</i>	<i>Iron</i>	<i>Vita- min A</i>	<i>Thia- mine</i>	<i>Ascorbic Acid</i>	<i>Ribo- flavin</i>
Milk, pasteurized	1 quart	6.66	16.8	46.1	1.8	12.2	7.0	8.5	35.2
Dates	6 dates	1.20	0.5	1.2	2.3	0.5	0.7	0	0.5
Orange juice, fresh	$\frac{3}{4}$ cup	0.81	0.7	1.4	1.5	(2.3)	2.9	41.6	1.8
Apples	2 medium	1.60	0.3	0.6	2.1	1.6	2.2	6.1	1.6
Potatoes, cooked	4 medium	4.00	4.8	2.4	9.6	0.4	9.6	34.4	4.0
Cabbage, raw	1 cup, shredded	0.21	0.6	1.6	1.1	0.4	1.1	18.8	0.9
Peas, cooked	$\frac{3}{4}$ cup	0.83	2.9	1.1	5.9	5.6	6.0	7.7	3.3
Beans, string, cooked	1 cup	0.27	0.9	1.8	2.4	5.3	1.8	7.7	2.4
Lettuce	$\frac{1}{2}$ head	0.15	0.6	0.9	1.3	2.5	1.4	4.7	1.2
Rolls, white, enriched	2 rolls	2.36	3.4	1.6	3.6	0	3.6	(0)	2.4
Bread, whole wheat	5 slices	3.40	6.5	5.5	8.0	0	9.0	0	4.0
Crackers, Graham	5 large	2.00	2.0	0.4	2.6	(0)	3.2	0	1.2
Oatmeal, cooked	2 $\frac{1}{4}$ cups	3.33	6.0	1.8	10.1	(0)	9.9	(0)	2.3
Flour, white, enriched	$\frac{1}{2}$ cup	3.20	4.6	0.5	6.7	0	7.7	0	4.6
Bacon, broiled	5 slices	2.00	4.0	0.4	2.6	(0)	3.2	0	2.0
Beef, roasted	5 oz.	4.20	16.0	0.5	10.9	(0)	2.0	0	5.0
Eggs	2 eggs	1.50	6.0	2.0	6.8	7.0	1.6	0	5.2
Butter or margarine	4 $\frac{1}{2}$ tbsp.	4.50	0.2	0.5	0	13.3	Trace	0	0.1
Drippings	2 tbsp.	2.52	0	0	0	0	0	0	0
Mayonnaise	2 tbsp.	2.00	0.2	0.2	0.6	0.4	0.0	0	0.4
Sugar	5 tbsp.	2.50	0	0	0	0	0	0	0
Molasses	3 tbsp.	1.50	(0)	7.5	10.2	(0)	0.9	(0)	2.1
Totals from diet		50.64	77.0	78.0	90.1	51.5	73.8	129.5	80.2
Recommended daily allowances		50.00	48	56	39	32	37	42	48

very liberal supply of minerals and vitamins. She is not so much interested in the foods mainly valuable for their calories, such as breakfast foods and bread, but milk should still be used freely to maintain a high intake of calcium and of vitamin A, thiamine, and riboflavin. The fruits and vegetables should be kept as high as finances permit. A girl's desire for food being less urgent, and sweet food making a strong appeal, the liberal use of fruits is to be encouraged. Salads twice a day are desirable for her, too, and the daily inclusion of an egg is another excellent safeguard.

The simple rules which were used as a guide for planning menus for the high school boy can be used equally well for the high school girl. The chief difference is in the total number of calories needed. A day's menus showing how these foods may be combined in simple but attractive meals will be found below.

A DAY'S MENUS FOR A HIGH SCHOOL GIRL

<i>Breakfast</i>	<i>Luncheon</i>	<i>Dinner</i>
Stewed dried apricots and figs	Vegetable and barley soup	Grapefruit and orange juice
Wheatflakes	Hard roll and butter	Veal cutlet
Toasted muffin with butter and straw- berry preserve	Carton of milk	Mashed potato
Milk to drink	Ice cream	Stewed tomatoes
	Peanut cookies	Romaine with Roquefort dressing and crackers
	<i>After School</i>	Floating island
	Egg and milk shake	

The itemized list of the foods needed for the preparation of these menus with the contributions of each food shows that the milk alone supplies most of the recommended allowance for calcium, while all the vegetables and fruits together furnish only about one-seventh as much as the milk. The vegetables and fruits supplement the milk as to iron, yielding one-fourth of the total iron in the diet.

The most prominent source of vitamin A is the Romaine but the milk, apricots, and soup vegetables are also good sources. Here again, milk, butter, and egg provide a large part of the total vitamin A. On other days when the thiamine requirement might not be as well met as on this day, it would be a good plan to add some wheat germ to the cereal, or even to substitute wheat germ for it entirely in order to give the girl at this critical age a generous supply of the B vitamins, so essential to good appetite and digestion.

Daily use of citrus fruit in liberal amounts will cover the actual requirement for ascorbic acid and the additional sources meeting the

A DAY'S DIETARY FOR A GIRL REQUIRING 2,400 CALORIES

Shares Contributed to the Diet

<i>Foods</i>	<i>Measure</i>	<i>Cal- ories</i>	<i>Pro- tein</i>	<i>Cal- cium</i>	<i>Iron</i>	<i>Vita- min A</i>	<i>Thia- mine</i>	<i>Ascorbic Acid</i>	<i>Ribo- flavin</i>
Milk, pasteurized	1 quart	6.66	16.8	46.1	1.8	12.2	7.0	8.5	35.2
Grapefruit and orange juice, (canned)	$\frac{1}{2}$ cup	0.50	0.4	0.5	0.9	0.4	1.1	19.7	0.4
Apricots, dried, cooked	4 halves	0.40	0.4	0.5	2.0	7.2	0.0	0.6	0.4
Figs, dried	2 medium	1.00	0.7	2.8	2.1	0.2	1.0	0	0.8
Soup vegetables	$\frac{3}{4}$ cup	0.20	0.4	0.3	1.0	10.9	0.9	2.0	0.3
Tomatoes, stewed	$\frac{1}{2}$ cup	0.22	0.6	0.2	1.5	7.8	1.4	7.9	0.7
Potato, cooked	1 medium	1.00	1.2	0.6	2.4	0.2	2.4	8.1	1.6
Romaine	6 large leaves	0.08	0.3	1.4	1.6	14.0	0.8	2.6	1.6
Muffin, enriched	1 muffin	1.34	1.9	1.5	2.1	0.3	1.8	(0)	2.0
Roll, white, enriched	1 roll	1.18	1.7	0.8	1.8	0	1.8	(0)	1.2
Wheatflakes, enriched	$\frac{8}{8}$ cup	1.00	1.5	0.5	3.2	(0)	3.2	0	1.0
Barley, entire	1 tbsp.	0.50	0.6	0.1	0.8	(0)	0.4	0	0.2
Crackers, whole wheat	3 small	0.60	0.6	0.1	0.8	(0)	1.0	0	0.4
Flour, enriched	1 $\frac{1}{2}$ tbsp.	0.33	0.5	0.1	0.7	0	0.8	0	0.5
Meat stock	$\frac{1}{2}$ cup	0.05	(0.5)	0.0	1.3	0	0	0	0.5
Peanuts	8 kernels	0.40	1.0	0.2	0.3	0	0.4	(0)	0.2
Veal cutlet	piece, 3" x 1 $\frac{3}{4}$ " x 1"	2.00	11.8	0.6	9.4	(0)	2.7	—	5.1
Eggs	1 $\frac{1}{2}$	1.00	4.0	1.3	4.5	4.7	1.1	0	3.5
Cheese, Roquefort	$\frac{1}{2}$ tbsp. grated	0.50	1.5	1.7	0.4	1.1	0.1	0	1.6
Ice cream	$\frac{1}{2}$ cup	2.00	1.8	4.8	0.3	3.2	0.8	0.4	3.6
Butter	2 tbsp.	2.00	0.0	0.2	0	5.0	Trace	0	0.0
Salad oil	$\frac{1}{2}$ tbsp.	0.50	0	0	0	0	0	0	0
Sugar	2 tbsp.	1.00	0	0	0	0	0	0	0
Jam	1 tbsp.	0.56	0.0	0.1	0.2	0.0	0.1	0.5	0.1

Totals from diet

25.02 48.2 64.5 39.2 68.2 28.8 50.3 60.3

4 Recommended daily allowances

24.00 38 52 39 32 25 34 38

recommended allowance may be regarded as good health insurance, keeping the tissues well saturated.

Vitamin D must be provided for in some regular way, and although cod liver oil is excellent for the purpose, on the other hand vitamin D milk may be a more convenient source.

Section 3. THE SCHOOL LUNCH PROGRAM

The earliest records of feeding groups of children in the United States date back to the middle of the nineteenth century when such programs were started in our large cities by voluntary societies. The Children's Aid Society of New York served some meals at its vocational school in 1853. Programs of this nature increased rapidly and by the turn of the century many were underway, but it was not until June 4, 1946, that the National School Lunch Act was made effective, thus making the school lunch available to all children. This is the most important practical step ever taken by our government to improve the health of all children through improvement in their nutrition.

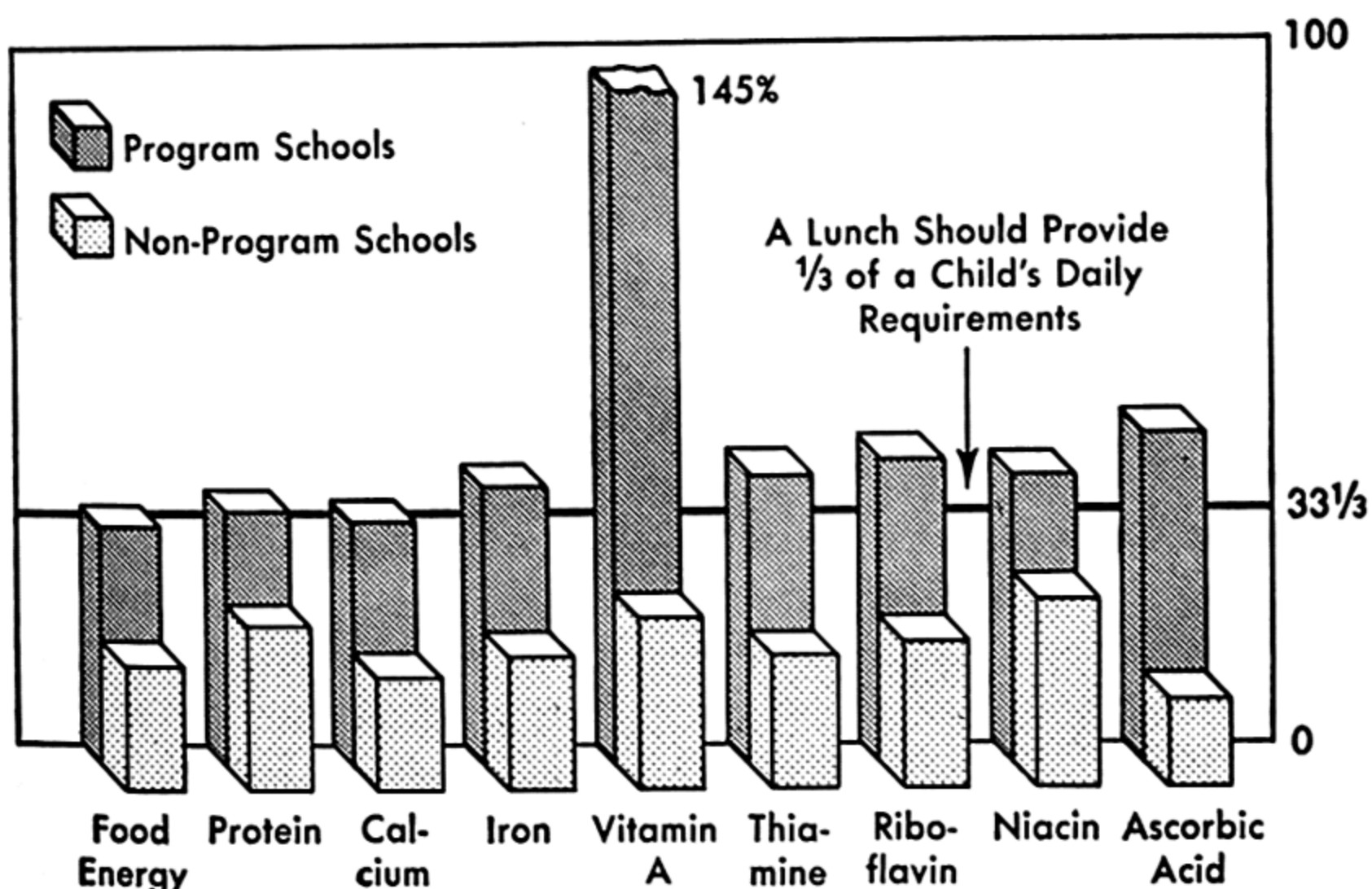
The educational opportunities which a well-organized school lunch program provides for the establishment of good food habits are unlimited. The school lunch program is a community affair and has brought many a mother to the school because she was interested in participating in the program. Space does not permit an extended discussion of the many advantages of the program, but we do want to call attention to the patterns for two types of school lunches used in the United States. These are listed below.

The third type known as "Type C" consists of $\frac{1}{2}$ pint of whole

	Type A	Type B
Milk, whole (as a beverage)	$\frac{1}{2}$ pint	$\frac{1}{2}$ pint
Protein food (any of the following or combinations thereof):		
Fresh or processed meat, poultry, cheese, cooked or canned fish	2 ounces	1 ounce
Beans or peas (dry) or soybeans, cooked	$\frac{1}{2}$ cup	$\frac{1}{4}$ cup
Peanut butter	4 tbsp.	2 tbsp.
Egg	1 egg	$\frac{1}{2}$ egg
Raw, cooked, or canned vegetables or fruits, or both	6 ounces	4 ounces
Bread, muffin or other hot bread made of whole grain cereal or enriched flour	1 portion	1 portion
Butter, or fortified margarine	2 tsp.	1 tsp.

milk. This program is for schools where no lunchroom facilities are available and in many states at the time of writing has been replaced by the special school milk program.

The nutritional advantage of the Type A school lunch is shown in Fig. 124.



(Courtesy of Human Nutrition Research Branch, Agricultural Research Service, USDA)

Fig. 124. Comparison of the nutritive value of the most frequently selected lunches in non-program schools with the type A lunches served in program schools. Each of these lunches in 1950 cost 22 cents.

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Adequate Diets for the Family

In a single family we expect to find differences of age—infants, children, and adults; differences of activity—the liveliest of children and the most sedate of parents; differences of taste—the boy whose sole criterion of a good meal is “enough” and the delicate damsel who cannot even peck at a meal unless the whole setting of the table appeals to her soul. Each member of the family group has his own particular food requirements which are matters of fact not fancy, and yet each claims a seat at the family table; for this is not merely the place where sustenance is furnished for the body; it is also a center of the social life of the group, offering important training in the graces of human intercourse and in the development of those esthetic standards of choice, preparation, and service of food which are an expression of the culture and refinement of the household.

In the majority of homes, the cost of food is a matter which requires much attention, but spending or saving must be done without impairing the nutritive value of the diet. A distinction must be made between food expenditures for nutriment and those for social purposes. Plain bread and milk make a most nutritious meal at a very low cost, but it is considered too simple and unpretentious to be served at a banquet; it would seem as incongruous as going in a gingham dress or overalls. Each family must determine for itself the relationship between the expenditure for actual nourishment and the additional sum to be allowed for enjoyment and entertainment and maintenance of social prestige. The influence of the education of the homemaker on the adequacy of the family diet is shown in Fig. 125.

As it is outside the scope of this book to consider in detail the social aspects of the food problem, this discussion will be confined to

the food requirements of representative family groups and plans for meeting them successfully so far as nutrition is concerned.

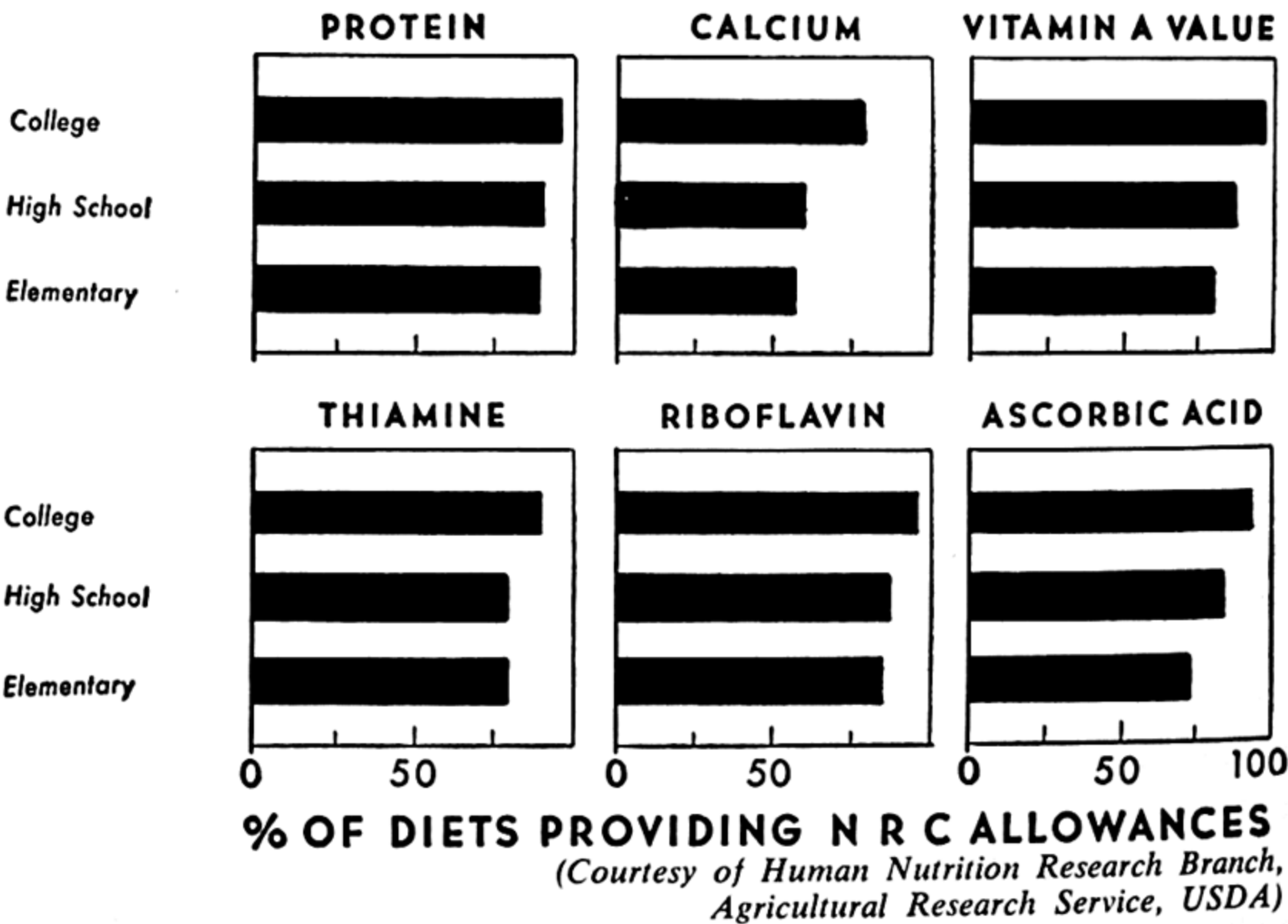


Fig. 125. Education of Homemaker and Adequacy of Family Diet
City families with incomes of \$3,000–\$4,000, Spring 1948.

While the requirements of the individual members may seem to differ considerably, the divergences are more in quantity and mode of service than in kind of food. With minor adjustments, it is possible to keep those who are six, sixteen, thirty-six, and forty-six well and happy on meals composed of practically the same ingredients, if suitably cooked and apportioned with discretion. Infants and children young enough to require specially prepared food are best cared for by themselves. They are not only likely to have a more carefully selected diet, but the children can also be more comfortably trained in good eating habits.

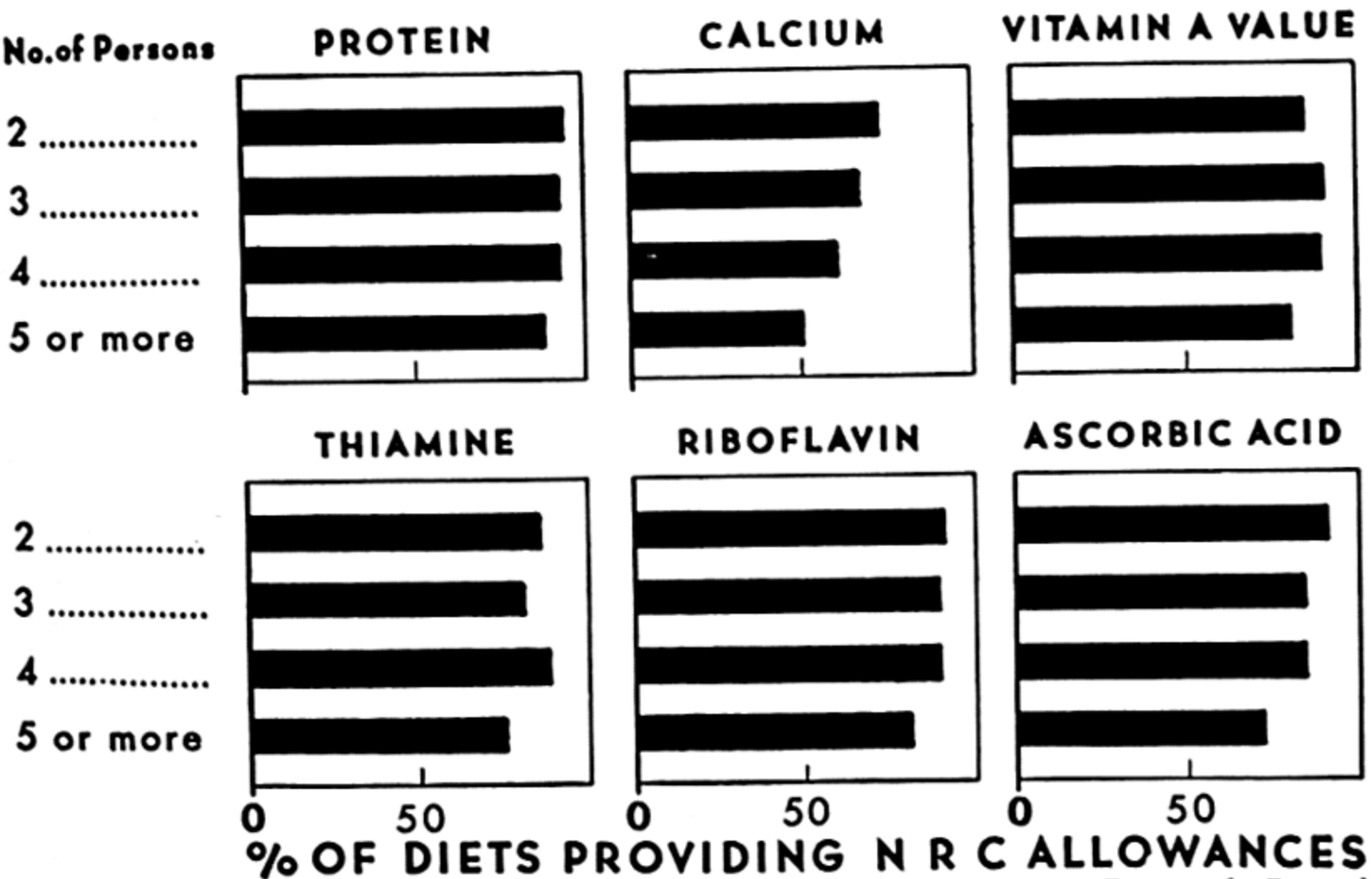
Desirable percentage distributions of calories in the diets of families of different income levels will be found in Table XVI.

The Dietary for a Family at Moderate Cost

Before selecting foods for a given family we must consider first the make-up of the family, that is, the number in the family, their

ages, activities, and the per cent of the income available for food. Fig. 126 shows graphically the influence of family size on the adequacy of the family diet.

The requirements of the family group will, of course, be the sum of those of the individuals composing it. Suppose, for example, we consider a family consisting of a father, mother, and three children.



(Courtesy of Human Nutrition Research Branch, Agricultural Research Service, USDA)

Fig. 126. Family Size and Adequacy of Family Diet
City families with incomes of \$3,000–\$4,000, Spring 1948.

Of the three children, two are in the elementary school, a boy 11 years of age and a girl of 8 years, and one is a preschool child, a boy of 4 years. Taking the recommended daily calorie allowances for the “standard” man and woman of at least thirty-five years in age and weighing approximately 70 and 55 kilograms respectively, it will be noted in Table III(b) in the Appendix, that the father of this family needs 3,225 calories and the mother 2,200 calories per day. The allowances for other nutrients expressed in shares corresponding to these calorie requirements for adults will be found in Table I(b). The recommended daily allowances for children will be found in Table I(c). The requirements for each member of the family can now be summarized as follows:

RECOMMENDED DAILY ALLOWANCES FOR A FAMILY
WITH A MODERATE INCOME

	<i>Shares</i>								
	<i>Cal- ories</i>	<i>Cal- ories</i>	<i>Pro- tein</i>	<i>Cal- cium</i>	<i>Iron</i>	<i>Vita- min A</i>	<i>Thia- mine</i>	<i>Ascor- bic Acid</i>	<i>Ribo- flavin</i>
Father	3,225	32.25	34	32	32	32	32	32	32
Mother	2,200	22.00	27	32	32	32	22	30	28
Boy (11 yrs.)	2,500	25.00	34	48	32	29	26	32	36
Girl (8 yrs.)	2,000	20.00	30	40	26	22	20	26	30
Boy (4 yrs.)	1,500	15.00	24	40	20	15	15	19	23
Total	11,425	114.25	149	192	142	130	115	139	149

The 3,225 calories allotted to the father of this family would meet the energy expenditure of a clerk or salesman who has to do some walking but little heavy manual labor. The mother's energy allowance would take care of the daily tasks about the home but would not be high enough to allow for the heavy cleaning and laundry work. The energy allowances for the children are average allowances for healthy children of the ages stated.

Since we have already demonstrated that the simple rules for the choice of foods serve as a satisfactory guide in the selection of adequate diets for individual adults and children, we may safely use them in feeding the family group.

In selecting food for this family, then, we should provide a quart of milk each day for each of the children and a pint of milk for each adult. This means 4 quarts daily for the family.

If we allow at least $\frac{1}{2}$ cup of citrus fruit juice per person per day, then for a family of five we would need $2\frac{1}{2}$ cups. Tomato juice can be used part of the time for variety since it also is a fairly good source of ascorbic acid.

An allowance of $\frac{1}{2}$ cup of a green leaf vegetable or its equivalent should be included four or five times a week for each member of the family. The four-year-old should be given a smaller portion. This would mean almost $2\frac{1}{2}$ cups of green leaves (cooked measure) for a family of five and in the case of spinach would amount to about $1\frac{1}{2}$ pounds as purchased. If generous amounts of dark green

leaves are included in a salad, the cooked greens can be omitted. Since yellow vegetables rank high for their vitamin A content, they can be used on alternate days or occasionally as desired.

One potato each day would mean five for the family, including a small one for the four-year-old and a larger one for his father. This would amount to $1\frac{2}{3}$ to 2 pounds each day.

With a recommendation of one egg daily or at least three a week for each member of the family, the weekly order for eggs would be between $1\frac{1}{4}$ and 3 dozen. The number used daily would depend, of course, upon the menus. Eggs are especially significant in the diet of young children.

The meat allowance is 4 or 5 ounces per day for adults and less than this for children, with probably not more than 2 ounces for a child of four. This would mean that 1 to $1\frac{1}{4}$ pounds would be enough for one day for this particular family. Meat is almost invariably one of the expensive items and since its cost is out of proportion to its nutritive value, it should be included in the main course for dinner not more than four or five times a week. Liver, which is much richer in iron and vitamin A, thiamine, and riboflavin, gives a much better return in nutritive value than muscle meats. Fish (fresh, canned, or frozen), eggs, poultry, and cheese may be regarded as alternatives for meat.

The bread allowance of four to six slices per person per day would amount to 1 to $1\frac{1}{2}$ pounds per day for a family of five. The bread used should be whole wheat or enriched and if hot breads are included in the menu they should be made with enriched flour. Cereal in some other form is desirable and is usually included in the breakfast. Either the cooked or ready-to-eat cereal may be used and here again it is desirable to use the whole grain cereals or those to which vitamins have been added.

Menus for one day at moderate cost planned with the preceding suggestions for the choice of food in mind will be found on page 504 and the contributions of the foods needed for their preparation on page 505.

An examination of the day's dietary reveals that when the total contributions of these foods are compared with the recommended daily allowances for this family, the diet is exceedingly well protected in respect to each of the nutrients.

The milk, as would be expected, furnishes almost enough calcium

to meet the daily recommended allowance, the other foods contributing only small amounts which help to provide a small but desirable surplus. It will be noted that part of the milk is evaporated, one large can replacing one quart of the fresh milk. The evaporated milk is cheaper than the fresh and can be used in the preparation of the muffins, chocolate pudding, and the creamed eggs. Except for ascorbic acid, the evaporated milk has practically the same nutritive value as the fresh milk. Milk is also the outstanding source of protein and riboflavin as well as being a good source of vitamin A and thiamine. Vitamin D milk or evaporated milk (with vitamin D added) will take care of the vitamin D requirement.

MENUS FOR ONE DAY FOR A FAMILY AT MODERATE COST ^a

<i>Breakfast</i>	<i>Luncheon</i>	<i>Dinner</i>
Grapefruit juice	Bouillon with whole	Baked Virginia ham
Dark farina (Wheat- ena), milk and sugar	wheat crackers	Browned potatoes
Toast, enriched bread, with butter or mar- garine	Spinach ring with creamed eggs	Yellow squash
Milk for children	Muffins with butter or margarine	Lettuce with French dressing
Coffee with milk and sugar, for adults ^b	Orange and banana salad	Whole wheat bread with butter or margarine
	Milk to drink	Chocolate blanc mange with whipped cream
		Milk for children

^a The luncheon salad may be omitted for the four-year-old and orange cut in small pieces given in its place. The dinner salad can either be omitted entirely for the four-year-old since there are other vegetables, or a small portion can be given without the dressing.

^b Coffee and tea are not essential but may be served in moderate amounts to adults at any meal as desired.

The oranges and the grapefruit juice furnish more than the recommended allowance for ascorbic acid and the spinach and potatoes help to insure an even greater surplus, an asset not to be overlooked.

The greens, in this case spinach, provide an abundant surplus of vitamin A. Although this is from all appearances a greater surplus than necessary, it must not be forgotten that on the days when other vegetables are used in place of green ones, the surplus will not be as great. In Chapter 12, attention was called to the fact that in plants vitamin A occurs as the provitamin and may not be as efficiently utilized; therefore a surplus is considered desirable. Also, the body can store large amounts of vitamin A. Thus some of this surplus can be looked upon as a means of increasing the body re-

A MODERATE-COST DAY'S DIETARY FOR A FAMILY OF FIVE

Shares Contributed to the Diet

<i>Food</i>	<i>Measure</i>	<i>Cal- ories</i>	<i>Pro- tein</i>	<i>Cal- cium</i>	<i>Iron</i>	<i>Vita- min A</i>	<i>Thia- mine</i>	<i>Ascorbic Acid</i>	<i>Ribo- flavin</i>
Milk, pasteurized	3 quarts	19.98	50.4	138.3	5.4	36.6	21.0	25.5	105.6
Milk, evaporated	1 large can	5.67	14.0	39.9	2.1	10.7	5.8	1.6	29.6
Grapefruit juice	2½ cups	2.20	1.3	2.2	4.6	0.7	9.2	98.8	7.0
Oranges	4 medium	2.80	2.8	8.0	6.4	8.8	9.6	140.0	6.4
Banana	1 medium	1.00	0.7	0.4	1.8	3.1	1.0	4.7	1.2
Potatoes, cooked	2 lbs. A.P.	6.40	7.7	3.8	15.4	1.3	15.4	51.8	6.4
Spinach, steamed	1½ lbs. A.P.	1.20	7.3	*	24.8	353.3	7.3	60.3	18.7
Lettuce	1 head	0.60	2.3	3.5	5.2	9.9	5.6	18.7	4.8
Squash, Hubbard, steamed	1½ lbs. A.P.	2.05	4.1	4.1	8.8	173.8	4.3	11.2	11.0
Bouillon	3¾ cups	0.34	(3.8)	0.4	9.8	0	0	0	3.8
Flour, enriched	2½ cups	8.50	12.0	1.4	17.9	0	20.2	0	12.0
Crackers, whole wheat	12	2.40	2.4	0.5	3.1	(0)	3.8	0	1.4
Farina, dark (Wheatena), cooked	3½ cups	6.13	11.6	3.2	15.8	(0)	17.5	0	5.6
Bread, white, enriched	8 slices	5.04	8.0	5.6	8.8	0	9.6	0	6.4
Bread, whole wheat	8 slices	5.44	10.4	8.8	12.8	0	14.4	0	6.4
Cocoa	¼ cup	0.94	1.5	1.7*	10.4	(0.1)	0.8	0	2.6
Cornstarch	¼ cup	1.16	0.1	(0)	(0)	(0)	(0)	(0)	(0)
Ham	1 lb.	18.04	51.2	1.8	34.7	(0)	49.2	0	19.2
Eggs, cooked	5	3.75	15.0	5.0	17.0	17.5	4.0	0	13.0
Butter or margarine	9 tbsp.	9.00	0.4	1.0	0	26.5	Trace	0	0.3
Salad oil	5 tbsp.	5.00	0	0	0	0	0	0	0
Cream, heavy	3 tbsp.	1.50	0.5	1.4	0.0	5.7	0.3	0.0	0.9
Shortening	1½ tbsp.	1.13	0	0	0	0	0	0	0
Sugar	¾ cup	5.14	0	0	0	0	0	0	0
Coffee	2 tbsp.	0.00	0	0	0	0	0	0	0

Totals from diet	115.41	207.5	231.0	204.8	647.9	199.0	412.6	262.3
Recommended daily allowances	114.25	149	192	142	130	115	139	149

* Availability doubtful.

serves just as putting money into a savings account provides a fund which can be drawn upon in an emergency. The greens are also needed in this dietary because they contain fairly large amounts of both iron and riboflavin.

The ham makes the outstanding contribution of thiamine. It is a better source of thiamine than any other meat, and on days when other meats are used the total surplus would undoubtedly be reduced. The cereals should be considered collectively and when so treated contribute more thiamine than the ham. The milk is next in importance and the contributions of the oranges and potatoes must not be disregarded. The potatoes and whole grain cereals are inexpensive sources of thiamine.

Taken in groups, the vegetables contribute about 54 shares of iron, the cereals 58, and the eggs and ham 52. Looking at the iron furnished by individual foods, it is clear that we cannot rely on any one food as a sole source of iron but must count on a number of foods to make up the total allowance.

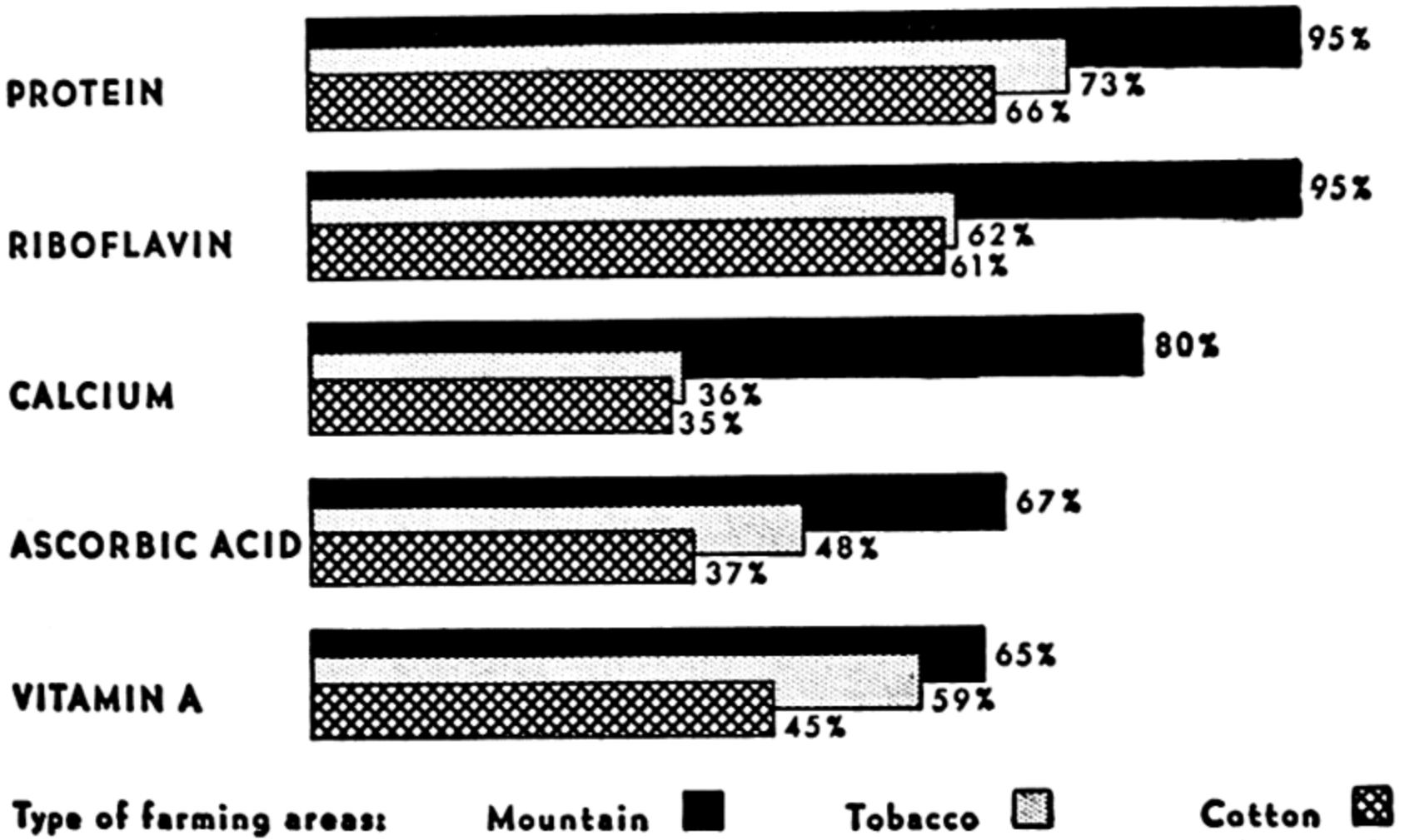
With these plans for one day as an example of a moderately priced adequate diet for a family of five, it will be easy to make plans for a diet for a week or longer. If the make-up of the family is different from the one that has been chosen as an example, other allowances can be made according to the number in the family, their ages, and occupations. See Appendix, Table XII, for suggested market list for one week and Table XVI(f) for a suitable percentage distribution of the calories.

How the area in which a family lives may influence the diet from the standpoint of meeting the recommended allowances is interestingly shown in Fig. 127.

The Dietary for a Family at High Cost

While it is an easy matter to obtain an adequate diet when there are no cost restrictions, it does not follow that with plenty of money to spend for food, diets will just naturally be good. Stiebeling of the Agricultural Research Service, United States Department of Agriculture, found this to be the case in a nation-wide study of diets of village and city families. When the quality of the diets of families in the northern and western sections of the United States was compared with the amounts spent for food per person per week, she found that although the per cent of the families having good diets was greater

where the food allowance was generous, there were, nevertheless, some families in the high-income group whose diets were classified as poor. That there should be any poor diets on a liberal food allow-



(Courtesy of Human Nutrition Research Branch, Agricultural Research Service, USDA)

Fig. 127. Diets Meeting NRC Allowances
Southern farm families, week in February–April 1948.

ance is shocking since for the most part it is due to factors which can be controlled, such as bad food habits, food notions, poorly prepared food, or too much dependence on appetite as a guide.

When the diets were compared on the basis of the abundance of protective foods, it was observed that where more money was available for food the quantities of protective foods were greater.

The possibility of having more protective foods makes the thought of planning diets without cost restriction a real delight. There is no end to the pleasing combinations which an unlimited food budget makes it possible to indulge in. It is fun indeed just to pause long enough to think of the great variety of foods available in American city markets under normal conditions. No place in the world offers such a choice of foods and they may be found at all seasons of the year and irrespective of transportation difficulties. Under normal conditions almost any whim can be satisfied for the asking if one can pay the price. Many of these more expensive foods have much to

offer the epicure nutritionally as well as from the standpoints of flavor, texture, and esthetic appeal. A few of these delicacies will be found in the table on page 509 along with the nutritive values of portions commonly served.

In glancing through the foods listed, it will be observed, for example, that the Roquefort cheese, the clams, and the oysters make rather significant contributions of calcium. The other foods in the list, as would be expected, contain less calcium and with the exceptions of artichoke, Camembert cheese, caviar, celery, lobster, and olives fail to carry even their quota.

These foods on the whole show up better as sources of iron. The oysters and clams are the best in the list, while squab, filet mignon, paté de foie gras, and sweetbreads also make outstanding contributions of iron.

Many of these foods are usually good sources of the vitamins. The mango heads the list for vitamin A while persimmons, shad roe, and paté de foie gras make significant contributions toward the recommended daily allowance of vitamin A.

None of these foods would be selected primarily for their thiamine content although it will be noted that many of them carry more than their share of thiamine when compared with their respective calorie shares. Shad roe contributes, for example, about fourteen times its quota of thiamine.

As a source of riboflavin the sweetbreads top the list with 11 shares. Among the other foods making significant contributions we find clams, paté de foie gras, oysters, Camembert cheese and frog's legs.

The mango stands out as a source of ascorbic acid, contributing more than the daily recommended allowance for ascorbic acid. Persimmons and the avocado carry several times their share of ascorbic acid while the honeydew melon carries more than thirty times its quota.

Thus the art of good eating need not be sacrificed to meet the requirements of an adequate diet. The gastronomist does not need to cramp his style but rather needs to extend his knowledge of food values so that he will be better equipped to select foods from the standpoints of both their psychological appeal and nutritive value. A clever epicure will not be baffled by this challenge and will find the planning of his menus more fun than ever before.

In making plans for a day's dietary for a specific family of high

NUTRITIVE VALUES OF SOME MORE EXPENSIVE FOODS IN SHARES

Shares Contributed to the Diet

<i>Foods</i>	<i>Measure</i>	<i>Cal- ories</i>	<i>Pro- tein</i>	<i>Cal- cium</i>	<i>Iron</i>	<i>Vita- min A</i>	<i>Thia- mine</i>	<i>Ascorbic Acid</i>	<i>Ribo- flavin</i>
Anchovies, canned	4 small filets	0.28	1.5	0.1	0.4		—		(0.7)
Artichokes, French	1 medium	0.64	1.4	1.6	2.7	1.3	1.6	3.7	0.6
Avocado	½ pear	1.63	0.5	0.3	1.0	1.3	0.8	4.7	1.7
Caviar	1 tbsp.	0.15	0.8	0.7	0.2		0		
Celery	1 heart	0.10	0.4	1.1	0.7	0	0.6	1.7	0.4
Cheese, Camembert	1 sector	1.35	3.9	1.9	0.6	3.0	0.4	(0)	6.7
Cheese, Roquefort	1 sector	1.68	4.9	5.7	1.3	3.5	0.3	0	5.4
Clams, long (soft shell)	12 clams	2.00	15.4	9.4	(45.2)	1.8	4.8	—	8.8
Cream (40%)	2 tbsp.	1.00	0.3	0.9	0.0	3.8	0.2	0.0	0.6
Filet mignon	4 oz. A.P.	3.30	9.0	0.5	7.4	—	2.4	0	3.2
Frog's legs	4 oz.	0.82	9.2	0.8	3.2	0	3.2	—	5.8
Honeydew melon	½ cup balls	0.21	0.1	(0.5)	(0.7)	0.2	0.7	6.5	0.4
Lobster meat	½ cup	0.67	6.6	1.9	1.6	0.7	(0.7)	—	1.1
Mango	1 medium	1.32	0.6	0.8	1.0	81.4	2.4	35.6	2.4
Olives, ripe	2 large	0.32	0.2	0.6	0.7	0.1	Trace	—	Trace
Oysters, raw	5 medium	1.00	5.8	4.5	18.7	1.9	5.8	1.7	8.4
Paté de foie gras	1 tbsp.	0.93	1.1	0.1	6.1	9.8	0.1	2.8	8.8
Persimmons	1 medium	0.95	0.5	0.3	1.1	21.0	1.2	5.6	1.0
Shad roe	½ medium	1.40	12.9	0.9	3.2	12.8	20.0	2.1	2.0
Squab	½ small	1.55	5.2	0.2	4.0	—			—
Sweetbreads, beef	½ pair	3.44	5.8	0.6	4.2		3.0		11.0

income, it is essential that the make-up of the family be considered in order that dietary allowances can be set up. Probably the father of this family will be doing a great deal of desk work which entails only a small expenditure of energy since the activity involved is chiefly sitting. Consequently, the calorie allowance need not be more than 2,525 calories. The mother, probably doing little of her housework, would undoubtedly need no more than 2,200 calories. The children of course need calorie allowances in accordance with their ages and if there are three children, two boys of nine and seven years and a girl of three years, they would need approximately 2,200, 1,900, and 1,300 calories respectively. See Tables III(b) and I(c) in the Appendix. The sum of these individual calorie allowances for this family of five is 10,125 calories for the day. Allowances for the other nutrients will be found in Tables I(b) and I(c) in the Appendix and are summarized below.

RECOMMENDED DAILY ALLOWANCES FOR A FAMILY
WITH A HIGH INCOME

	<i>Shares</i>								
	<i>Cal- ories</i>	<i>Cal- ories</i>	<i>Pro- tein</i>	<i>Cal- cium</i>	<i>Iron</i>	<i>Vita- min A</i>	<i>Thia- mine</i>	<i>Ascor- bic Acid</i>	<i>Ribo- flavin</i>
Father	3,725	37.25	34	32	32	32	32	32	32
Mother	2,200	22.00	27	32	32	32	22	30	28
Boy (9 yrs.)	2,200	22.00	32	40	28	25	22	28	32
Boy (7 yrs.)	1,900	19.00	28	40	24	20	20	24	28
Girl (3 yrs.)	1,300	13.00	22	40	19	14	14	17	21
	<u>10,125</u>	<u>101.25</u>	<u>143</u>	<u>184</u>	<u>135</u>	<u>123</u>	<u>104</u>	<u>131</u>	<u>141</u>

In planning the menus for this family of high income, the simple rules of nutrition can be used for the choice of protective foods as they were used for the family of moderate income. However, the choices may be made from a greater variety of foods since the selection is not curtailed by the cost.

Menus have been planned keeping these facts in mind as a guide and are given below. In looking over the menus it will be easy to check them against the simple rules of nutrition. Four quarts of

fresh pasteurized milk or 1 pint for each adult and 1 quart for each child have been included to insure sufficient calcium. Instead of fruit juice for ascorbic acid, fresh fruit has been selected for this particular day and the salad greens have been included for vitamin A instead of a cooked green leaf vegetable.

MENUS FOR ONE DAY FOR A FAMILY AT HIGH COST ^a

<i>Breakfast</i>	<i>Luncheon</i>	<i>Dinner</i>
Honeydew melon	Creamed oysters in	Grapefruit salad on en-
Wheat flakes with milk	toast cups	dive
and sugar	Toast fingers	Lamb chops
Shirred eggs	Salad bowl (mixed	Buttered peas and mush-
Toast, whole wheat, with	greens)	rooms
butter or margarine	Fresh blueberries with	Parsley potatoes
Milk for children	cream and sugar	Grilled tomatoes
Coffee for adults ^b with	Milk to drink	Dinner rolls with butter
cream and sugar		or margarine
		Pineapple sherbet
		Milk for children
		Coffee for adults ^b with
		cream and sugar

^a Modifications of these menus suggested for the three-year-old child: Substitute orange juice for the honeydew melon for breakfast. Omit the egg for breakfast and serve at the noon meal with mashed potato and cooked chopped carrots. Cook $\frac{1}{2}$ cup of blueberries and serve for luncheon dessert instead of the fresh berries. At the evening meal, give milk toast, puréed peas, and stewed prunes.

^b Coffee and tea are not essential but may be served in moderate amounts to adults at any meal as desired.

Shirred eggs have been included in the breakfast menu, one egg being the allowance for each member of the family. Large lamb chops have been selected for dinner, each member of the family having a chop except the youngest child for whom milk and egg provide adequate protein for this particular day.

The cream is not an essential food item but it never fails to improve the flavor of food and since the high cost of food is not a problem in this dietary, cream has been allowed for the breakfast cereal, the blueberries, and the coffee. Because calories are greatly increased by the addition of cream, too much of it must be guarded against for the sake of both digestion and body weight.

The contributions of the food items making up the day's dietary will be found on page 513. In comparing the total contribution of these foods with the recommended daily allowances for this family, it will be seen at a glance that this sample diet for one day provides

very generous surpluses of each of the recommended specific nutrients. While some of these surpluses may be considerably higher than necessary, they should be regarded as desirable, especially since it cannot be assumed that each of the other days in the week will provide such a margin of safety.

The Dietary for a Family at Low Cost

Among people of very limited means the largest item in the budget is food, and there must be careful planning to have anything left for other necessities. Food economies can be effected in a variety of ways without sacrifice of nutritive value. The first move should generally be to increase the consumption of the foods from cereal grains, and to see that these are made the carriers of mineral constituents and vitamins so far as they are capable of yielding them. The use of a large proportion of the whole grain or enriched breads and cereals instead of the refined products is far more important here than in a diet where cereals contribute one-quarter or less of the total calories. The striking lesson that a diet of whole wheat and whole milk with a little added salt is capable of sustaining rats through more than eighty generations should be taken to heart. By skillful cookery it is possible to vary a diet in which cereals figure largely. Mrs. Ewing, a pioneer teacher of home economics and a famous maker of bread, used to say that she could keep any family contented with its meals if she could only make its bread.

Milk is always one of the best food investments that it is possible to make. Where fresh milk of good quality is not to be had at a fair price in comparison with other foods, it is now possible to get evaporated milk which can readily be reconstituted by adding an equal volume of water. It loses nothing of significance in the process of condensation except ascorbic acid, and this lack can be easily met with orange or tomato juice for infants and young children or by a variety of antiscorbutic fruits and raw vegetables in the diet of other members of the family group. Dried milk is also advantageous but if the dried skim milk powder is used the diet must be safeguarded for vitamin A. The water which is removed in the drying is replaced as easily as in evaporated milk. As a reserve for emergencies, or for safety when traveling, even if fresh milk is ordinarily used, these preparations are worthy of a place in the family larder. In some localities fluid skim milk is available and this can be used in place

A HIGH-COST DAY'S DIETARY FOR A FAMILY OF FIVE

Shares Contributed to the Diet

		Cal- ories	Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascorbic Acid	Ribo- flavin
<i>Foods</i>	<i>Measure</i>								
Milk, pasteurized	4 quarts	26.64	67.2	184.4	7.2	48.8	28.0	34.0	140.8
Pineapple, canned	1 cup	2.08	0.4	3.1	4.4	1.5	3.7	10.8	1.2
Blueberries	2½ cups	1.80	0.9	1.8	6.1	5.2	(1.1)	20.0	(1.1)
Grapefruit	1 large	2.00	1.2	4.4	4.2	0.6	8.0	85.4	6.0
Orange	1 small	0.50	0.5	1.5	1.2	1.6	1.8	25.7	1.1
Honeydew melon	½ melon	2.45	2.0	(5.1)	(8.3)	2.0	7.8	75.5	4.4
Prunes, dried	2 large	0.50	0.2	0.4	1.9	2.3	0.4	0.2	0.6
Potatoes, cooked	1½ lbs. A.P.	4.80	5.8	2.9	11.6	1.0	11.6	38.9	4.8
Tomatoes, grilled	2 medium	0.60	1.5	1.2	4.8	21.3	3.0	21.0	1.8
Parsley	3 sprigs	0.03	0.2	*	1.5	5.7	Trace	9.0	0.6
Peas, frozen	10 oz.	2.25	8.4	2.1	11.4	12.9	19.8	23.1	6.3
Mushrooms	½ lb.	0.77	3.6	1.2	6.0	0	6.3	3.0	26.0
Endive (curly)	7 oz.	0.42	1.4	6.3	9.1	(127.4)	2.8	9.1	12.6
Romaine	½ head	0.15	0.6	2.5	2.9	24.7	1.4	4.8	3.0
Radishes	10 small	0.20	0.6	1.5	2.6	0.2	1.4	7.7	0.6
Celery	½ cup	0.12	0.4	1.3	0.9	0	0.7	2.0	0.6
Carrot	1 medium	0.20	0.5	0.7	1.0	36.6	0.6	1.2	0.5
Wheat flakes, enriched	2½ cups	3.60	5.4	1.8	11.1	(0)	11.5	0	3.6
Bread, whole wheat	5 slices	3.40	6.5	5.5	8.0	0	9.0	0	4.0
Bread, white, enriched	7 slices	4.41	7.0	4.9	7.7	0	8.4	0	5.6
Rolls, enriched	4 rolls	4.72	6.8	3.2	7.2	0	7.2	(0)	4.8
Flour, enriched	½ cup	1.00	1.4	0.2	2.1	0	2.4	0	1.4
Egg white	1 white	0.15	1.6	0.1	0.0	(0)	0	0	1.5
Eggs, cooked	5 medium	3.75	15.0	5.0	17.0	17.5	4.0	0	13.0
Lamb chops, broiled	18 oz. A.P.	14.11	39.2	1.6	26.9	(0)	9.5	0	17.4
Oysters	12 medium	2.40	13.9	10.8	44.8	4.6	13.9	4.1	20.2
Butter	8 tbsp.	8.00	0.3	0.9	0	23.5	Trace	0	0.2
Cream, light	½ cup	2.72	1.9	5.2	0.4	7.1	0.8	0.5	3.7
Salad oil	5 tbsp.	5.00	0	0	0	0	0	0	0
Sugar	½ cup	3.85	0	0	0	0	0	0	0
Coffee	4 tbsp.	0.00	0	0	0	0	0	0	0
Totals from diet		102.62	194.4	259.6	210.3	344.5	165.1	376.0	287.4
Recommended daily allowances		101.25	143	184	135	123	104	131	141

* Not available.

of the whole milk if the vitamin A in the fat which is lost in the process of skimming is provided by the other foods in the diet.

Among vegetables and fruits economies must be sought in use of foods at the height of their season and not when out of season and therefore expensive. Purchasing should be done with regard to nutritive value rather than size or color, but every effort should be made in buying fresh vegetables to have them as fresh as possible, since both flavor and nutritive value depend so much upon this. All the vegetables should be cooked with regard to conserving mineral elements and vitamins.

Meat cannot figure prominently in an economical diet since it is usually the most expensive food. Even cheap cuts are not so very cheap, or else they consist largely of waste. Meat is appetizing and a good source of protein; therefore a certain amount, especially for adults, is desirable, but the quantity consumed at a meal need not be large, and should be used in such a way as to extend its flavor over as much bread and other bland food as possible, for thus it does its best service. What has been said about eggs and cheese in discussing moderately priced diets also applies here. Glandular meats such as liver (beef, lamb, or pork) and kidney will fortify the low-income diet with iron, vitamin A, thiamine, and riboflavin. One of these may well be included at least once a week.

Since the quantity of meat must be limited if the cost is to be kept low, it might be well at this point to compare the nutritive values of servings of other foods which may be used to replace meat. See Table II in the Appendix. An examination of the contributions of a few of these foods such as beans (various kinds), lentils, eggs, cheese, macaroni and cheese, salmon and other kinds of fish will show that some of them are poorer sources of protein but this can be remedied by the use of milk. It should be noted that in a number of cases these foods surpass meat for their contributions of iron, thiamine, and riboflavin; and the soybeans, salmon, and cheese dishes are superior as sources of calcium.

Butter or margarine can be used interchangeably in the diet since margarines are now well fortified with vitamin A and have a good flavor besides. A considerable saving in food expenditures can be made by using margarine.

Cream is always more expensive than milk, and in an economical diet should not be bought as such, but be taken from the milk pur-

chased. The habit of using milk instead of cream on cereals, puddings, etc., is a desirable one to cultivate.

Sugar and syrups, because of their attractive flavor and cheapness, tend to be used too freely in economical diets, displacing foods which are more important. Pure cane molasses is significant for calcium and iron and, in a family where there are growing children, may well be used to replace some cane sugar. As Sherman so aptly said: "In general the proper place of sugar in the food supplies and eating habits of children is not in such concentrated forms as candy, nor in the indiscriminate and excessive sweetening of all kinds of foods, but rather as a preservative and flavor to facilitate the introduction into the child's dietary of larger amounts of the fruit and the milk, the importance of which to child health has been increasingly emphasized with each year's progress in our knowledge of nutrition."¹ Jams and jellies unless made at home with fruits obtained at the height of the season at a reasonable price are too expensive a source of calories to be included very often in the low-income diet. The fruit obtained in this way is far too insignificant in quantity to play any important role in the dietary.

In setting up the requirements for an average family with little money to spend for food, the energy allowances should be higher since the father of this family would probably be doing heavy manual work and the mother would probably be doing her own housework including the laundry. If in a particular case this is not true and the father is not doing heavy work, then the calorie allowance needs to be adjusted to fit his requirements. If we again plan for a family of five, this time with three children of fourteen, six, and three years, and use Tables III(b), I(b), and I(c) in the Appendix, we can summarize the recommended daily allowances as follows:

RECOMMENDED DAILY ALLOWANCES FOR A FAMILY WITH A LOW INCOME

Shares

	<i>Cal- ories</i>	<i>Cal- ories</i>	<i>Pro- tein</i>	<i>Cal- cium</i>	<i>Iron</i>	<i>Vita- min A</i>	<i>Thia- mine</i>	<i>Ascor- bic Acid</i>	<i>Ribo- flavin</i>
Father	3,725	37.25	34	32	32	32	32	32	32
Mother	2,275	22.75	27	32	32	32	24	30	28

¹ Sherman, H. C. "The Problem of Sweets for Children," *Child Health Bulletin*, page 7. American Child Health Association, May 1929.

	Shares								
	Cal- ories	Cal- ories	Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascor- bic Acid	Ribo- flavin
Girl (14 yrs.)	2,500	25.00	39	52	39	32	26	34	40
Boy (6 yrs.)	1,700	17.00	26	40	22	18	18	22	26
Girl (3 yrs.)	1,300	13.00	22	40	19	14	14	17	21
Total	11,500	115.00	148	196	144	128	114	135	147

Taking the simple rules of nutrition again as our guide, and making our selections from foods of lower cost but of high nutritive quality, typical menus for one day can be planned such as those found below. The foods needed for the preparation of these menus are listed on page 517 along with their contributions.

MENUS FOR ONE DAY FOR A FAMILY AT LOW COST ^a

Breakfast	Luncheon	Dinner
Prunes	Spaghetti with tomato and cheese	Vegetable juice cocktail made from canned tomato and vegetable cooking water
Oatmeal, milk and sugar	Carrot and cabbage slaw, French dressing	Stuffed beef birds
Toast, enriched bread, with margarine	Peanut butter and raisin sandwiches (whole wheat bread)	Kale
Milk for children	Milk to drink	Potatoes, boiled in jackets
Coffee with milk and sugar, for adults ^b		Bread, whole wheat, with margarine
		Caramel custard
		Milk for children
		Coffee with milk and sugar, for adults ^b

^a The menus for this family are so simple that little modification is necessary for the three-year-old except the serving of smaller portions. A little raw carrot might preferably be given for lunch instead of the slaw.
^b Coffee and tea are not essential but may be served in moderate amounts to adults at any meal if the budget permits.

Comparing the total contributions of the foods needed for one day with the recommended allowances it can be seen that there is a good margin of safety in the case of each of the nutrients. This shows that if the foods are carefully selected, the nutritive quality of the diet need not be sacrificed when the income is low. The variety of foods meeting the low-cost requirements is, however, limited. In studying the list of foods for the day, it will be appreciated that the following choices have been made in order to reduce the cost.

- (1) Two large cans of evaporated milk replace two quarts of the fresh pasteurized milk.

A LOW-COST DAY'S DIETARY FOR A FAMILY OF FIVE

Shares Contributed to the Diet

<i>Foods</i>	<i>Measure</i>	<i>Cal- ories</i>	<i>Pro- tein</i>	<i>Cal- cium</i>	<i>Iron</i>	<i>Vita- min A</i>	<i>Thia- mine</i>	<i>Ascorbic Acid</i>	<i>Ribo- flavin</i>
Milk, pasteurized	2 quarts	13.32	33.6	92.2	3.6	24.4	14.0	17.0	70.4
Milk, evaporated	2 large cans	11.34	28.0	79.8	3.4	21.4	11.6	3.2	59.2
Potatoes, cooked	2½ lbs. A.P.	8.00	9.6	4.8	19.2	1.6	19.2	64.8	8.0
Kale, cooked	1½ lbs. A.P.	1.38	6.4	30.4	19.3	180.8	4.9	73.1	15.4
Tomatoes, canned	20 oz.	1.00	2.6	1.3	6.8	35.4	6.4	35.9	3.2
Cabbage, raw	9 oz.	0.63	1.8	4.9	3.5	1.3	3.2	55.3	2.6
Carrot, raw	1 medium	0.20	0.3	0.7	1.0	36.6	0.6	1.2	0.5
Onions, cooked	2 small	0.50	0.7	1.7	1.6	0.4	0.5	3.5	0.8
Prunes, cooked	½ lb. A.P.	3.36	1.4	2.7	12.8	15.3	1.5	1.0	4.3
Raisins	1 oz.	0.76	0.3	0.7	2.4	0.1	0.8	0	0.4
Bread, white, enriched	1 lb.	12.48	19.2	14.4	20.8	0	22.4	0	12.8
Bread, whole wheat	1 lb.	10.88	20.8	17.6	25.6	0	28.8	0	12.8
Oatmeal	6 oz.	6.66	12.2	3.6	22.2	(0)	19.8	(0)	4.5
Spaghetti, enriched	7 oz.	7.54	12.6	1.8	15.2	(0)	35.2	(0)	14.8
Cheese, Cheddar	1½ oz.	1.98	6.2	17.4	1.4	4.4	0.2	(0)	4.4
Chuck, boned	1 lb.	10.19	41.9	1.5	27.1	(0)	3.2	0	13.6
Eggs	2	1.50	6.0	2.0	6.8	7.0	1.6	0	5.2
Margarine, fortified	½ lb.	8.16	0.3	0.9	0.0	24.2	0.2	0	0.7
Peanut butter	3 oz.	4.92	11.0	2.6	3.9	0	2.1	(0)	2.7
Salad oil	2 tbsp.	2.00	0	0	0	0	0	0	0
Sugar	½ lb.	8.74	0	0	0	0	0	0	0
Coffee	4 tbsp.	0	0	0	0	0	0	0	0

Totals from diet

115.54	214.9	280.9	196.6	352.9	158.2	255.0	232.1
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Recommended daily allowances

115.00	148	196	144	128	114	135	147
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(2) Kale has been selected in place of one of the more expensive green leaf vegetables. Choices in this group can be made according to the prevailing market prices since dark green leaves are very much alike in nutritive value.

(3) Tomatoes and cabbage have been included for ascorbic acid. This along with the ascorbic acid coming from potatoes and kale provides an abundant supply.

(4) A liberal quantity of potatoes, one of the cheapest of the fresh vegetables, has been included and they furnish two to eight times their quota of iron, thiamine, and ascorbic acid.

(5) The cereals, largely whole grain or enriched, provide about 35 per cent of the total calories for the day. Since the cereals are an inexpensive source of calories and at the same time, if whole grain or enriched, are excellent sources of iron and thiamine, it is desirable to include them in large amounts.

(6) Margarine (fortified with vitamin A) has been used along with peanut butter, both of which are cheaper than butter and offer a good means of cutting expenses.

(7) The calories from meat and eggs contribute only about 10 per cent of the total calories for the day. These are expensive foods and the amounts recommended must be reduced to not more than one serving daily of either meat, eggs, or fish. Cheese, of course, can be used to give added flavor to cereal dishes and in other attractive ways to give a little piquancy to an otherwise bland product. It is illuminating to note that in this dietary if the meat were omitted entirely the other foods would more than take care of the recommended daily allowances for this family with the exception of the calories.

Three meals for another typical day's dietary for a family at low cost are shown in Fig. 128.

To put such programs into effect means considerable modification of most people's way of thinking about food and of planning meals. Milk has been regarded by too many as food only for babies; one mother expressed a not uncommon idea when she said, "My boy is fourteen years old and I am surprised to find that he can still digest milk!" But year by year the science of nutrition continues to make clearer and clearer that no better foundation for the diet can be found either for children or adults than a liberal amount of milk. Dietaries such as have been outlined in this chapter give

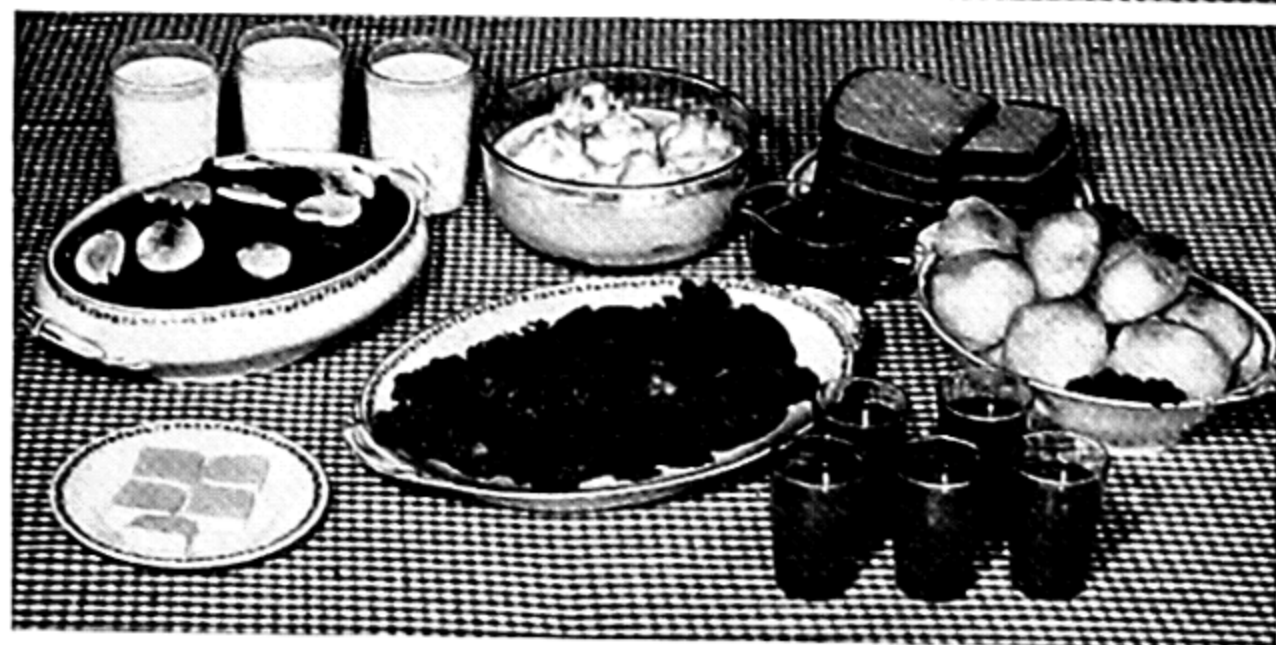
A



B



C



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in Forecast Magazine, Sept. 1941)

Fig. 128. Meals for One Day for a Family of Low Income

A. BREAKFAST

Stewed Prunes
Rolled Oats
Whole Wheat Toast
with Margarine
Milk for Children
Coffee for Adults
Evaporated Milk for
Cereal and Coffee

B. LUNCH

Spanish Rice (with
Cheese, Tomato and
Onion)
Cabbage Salad
French Dressing
Milk for Children and
Adults
Baking Powder Bis-
cuits with Mar-
garine

C. DINNER

Tomato Juice Cocktail
Breaded Hamburg
Steak Balls, Gravy
Boiled Potatoes
Kale with Egg Gar-
nish and Vinegar
Dressing
Whole Wheat Bread
and Margarine
Banana Custard with
Meringue
Milk for Children

little opportunity for fancy cooking. If the suggestions in this book are followed, milk soups, milk puddings, and many other milk dishes will become a prominent part of the regime unless the simpler method of drinking most of the milk is followed by all of the family. Knowledge of how to have a simple diet which is nutritionally the best should help busy housewives to lighten their labors in the kitchen and find time for other interests, such as a larger share in the education of their children. It ought to be a great comfort to a mother to know that she is doing her children a real kindness when she gives them a supper of plain bread and milk or cereal and milk. Scientific knowledge makes possible simplification of the menu without risk of an inadequate diet.

The situation is similar with regard to economy in food. To choose what will fit a slim purse regardless of nutritive value is likely to bring underfeeding on some count or other, perhaps on several counts at once. A common tendency when money is scarce is to secure calories largely from breadstuffs, sugars and syrups, plus muscle meat, with the result that the dietary is low in mineral constituents and vitamins.

What can be accomplished when foods are chosen with definite knowledge of what each is contributing is shown by a comparison of the three dietaries at different cost levels which have just been described. Since the recommended allowances for these three families are different, it seems best to make this comparison on the basis of the surpluses above the allowances which each of the three dietaries contribute. This has been done in the following table:

A COMPARISON OF THE NUTRITIVE VALUE OF THREE FAMILY DIETARIES DIFFERING IN COST

<i>Cost</i>	<i>Surplus Shares Contributed</i>							
	<i>Cal- ories</i>	<i>Pro- tein</i>	<i>Cal- cium</i>	<i>Iron</i>	<i>Vitamin A</i>	<i>Thia- mine</i>	<i>Ascorbic Acid</i>	<i>Ribo- flavin</i>
High	1.37	51	76	75	222	61	245	146
Moderate	1.16	59	39	63	518	84	274	113
Low	0.54	67	85	53	225	44	120	85

Regardless of the income level, it will be noted that each day's dietary provides generous surpluses of each of the specific nutrients. The lowest surpluses are found in the calorie column. This is as it should be since there is no virtue in storing up calories. The sur-

pluses of the other nutrients show no particular trends which can be lined up with the income level. This demonstrates clearly that it is the choice of foods which determines the nutritive quality of the diet rather than the income. However, since the choices are more limited when the income level is low, it is highly desirable that educational programs be sponsored in all communities where large proportions of the population have to live on restricted incomes. This can best be accomplished by engaging the services of a trained nutritionist who appreciates the many problems concerned with the choice of foods, including the economic aspects of marketing as well as the nutritive value and preparation of the food in the home.

That it will pay to master the art of selecting an adequate diet at any cost level has been the lesson taught by the most careful investigations in the field of nutrition. As Sherman said, "With heredity and all the conditions of environment except food the same, those enjoying the better diet are bound to inherit the earth."

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Appendix

Table I(a). RECOMMENDED DAILY ALLOWANCES IN SHARES

Age, Years	Weight Kg. (Lb.)	Height Cm. (In.)	Calories	Protein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascor- bic Acid	Ribo- flavin
Men	25	65(143)	170(67)	32.00	32	32	32	32	32	32
	45	65(143)	170(67)	29.00	32	32	32	30	32	32
	65	65(143)	170(67)	26.00	32	32	32	26	32	32
Women	25	55(121)	157(52)	23.00	27	32	32	24	30	28
	45	55(121)	157(52)	21.00	27	32	32	22	30	28
	65	55(121)	157(52)	18.00	27	32	32	20	30	28
	Pregnant (3rd trimester)			add 4.00	39	39	38	30	43	40
	Lactating (850 ml. daily)			add 10.00	49	39	51	30	64	45
(No specific recommendations)										
Infants	0-1 mo.									
	1-3 mo.	5(11)	58(23)	kg.x 1.20	kg.x 1.7	16	10	6	13	8
	4-9 mo.	8(18)	67(26)	kg.x 1.10	kg.x 1.7	16	10	8	13	14
	10-12 mo.	10(22)	75(30)	kg.x 1.00	kg.x 1.7	16	10	10	13	18
Children	1-3	12(27)	87(34)	12.00	20	18	13	12	15	20
	4-6	18(40)	109(43)	16.00	25	21	16	16	21	24
	7-9	27(59)	129(51)	20.00	30	26	22	20	26	30
Boys	10-12	35(78)	144(57)	25.00	34	32	29	26	32	28
	13-15	49(108)	163(64)	32.00	42	39	32	32	38	42
	16-20	63(139)	175(69)	38.00	49	39	32	38	43	50
Girls	10-12	36(79)	144(57)	23.00	34	32	29	24	32	36
	13-15	49(108)	160(63)	25.00	39	39	32	26	34	40
	16-20	54(120)	162(64)	24.00	37	39	32	24	34	38

These allowances have been calculated from the recommended dietary allowances suggested by the Food and Nutrition Board of the National Research Council, 1953, which will be found in Table III(a), page 556.

Table I(b). RECOMMENDED DAILY DIETARY ALLOWANCES FOR ADULTS TWENTY-FIVE YEARS AND OVER ACCORDING TO CALORIE REQUIREMENTS ^a EXPRESSED IN SHARES

<i>Calories</i>	<i>Pro- tein</i>	<i>Cal- cium</i>	<i>Iron</i>	<i>Vita- min A</i>	<i>Thia- mine</i>	<i>Ascorbic Acid</i>		<i>Riboflavin</i>	
						<i>Men</i>	<i>Women</i>	<i>Men</i>	<i>Women</i>
14.00-20.00	^b	32	32	32	20	32	30	32	28
21.00-22.00	^b	32	32	32	22	32	30	32	28
23.00-24.00	^b	32	32	32	24	32	30	32	28
25.00-26.00	^b	32	32	32	26	32	30	32	28
27.00-28.00	^b	32	32	32	28	32	30	32	28
29.00-31.00	^b	32	32	32	30	32	30	32	28
32.00-37.00	^b	32	32	32	32	32	30	32	28
38.00-42.00	^b	32	32	32	34	32	30	32	28
43.00-45.00	^b	32	32	32	36	32	30	32	28
12.00-14.00 (Reducing)	^b	32	32	32	20	32	30	32	28

^a Based on 1953 recommendations of the Food and Nutrition Board of the National Research Council.

^b Recommended allowance for protein is 0.49 share of protein per kilogram of body weight per day or 0.22 share of protein per pound of body weight per day.

Table I(c). RECOMMENDED DAILY DIETARY ALLOWANCES FOR CHILDREN EXPRESSED IN SHARES ^a

<i>Age, Years</i>	<i>Cal- ories</i>	<i>Pro- tein</i>	<i>Cal- cium</i>	<i>Iron</i>	<i>Vita- min A</i>	<i>Thia- mine</i>	<i>As- corbic Acid</i>	<i>Ribo- flavin</i>
<i>Infants</i>								
0-1 mo.	(no specific recommendations)							
1-3 mo.	kg.x 1.2	kg.x 1.7	24	16	10	6	13	8
4-9 mo.	kg.x 1.1	kg.x 1.7	32	16	10	8	13	14
10-12 mo.	kg.x 1.0	kg.x 1.7	40	16	10	10	13	18
<i>Children</i>								
1	11.00	18	40	17	12	11	14	19
2	12.00	20	40	18	13	12	15	20
3	13.00	22	40	19	14	14	17	21
4	15.00	24	40	20	15	15	19	23
5	16.00	25	40	21	16	16	21	24
6	17.00	26	40	22	18	18	22	26
7	19.00	28	40	24	20	20	24	28
8	20.00	30	40	26	22	20	26	30
9	22.00	32	40	28	25	22	28	32
<i>Boys</i>								
10	23.00	33	44	30	27	24	30	34
11	25.00	34	48	32	29	26	32	36
12	28.00	37	51	34	30	28	34	38
13	30.00	40	54	37	31	30	36	40
14	32.00	42	56	39	32	32	38	42
15	34.00	44	56	39	32	34	40	44
16	36.00	46	56	39	32	36	41	46
17	37.00	48	56	39	32	37	42	48

		<i>Girls</i>						
10	23.00	33	44	30	27	23	30	34
11	23.00	34	48	32	29	24	32	36
12	24.00	36	49	34	30	25	33	38
13	25.00	38	51	37	31	26	34	39
14	25.00	39	52	39	32	26	34	40
15	25.00	39	52	39	32	26	34	40
16	24.00	38	52	39	32	25	34	38
17	24.00	38	52	39	32	24	34	38

^a These allowances for children have been obtained by interpolation after calculating share values for the daily dietary allowances recommended by the Food and Nutrition Board of the National Research Council as revised in 1953.

Table I(d). RECOMMENDED DAILY DIETARY ALLOWANCES^a FOR YOUNG MEN AND WOMEN EIGHTEEN TO TWENTY-FOUR YEARS OF AGE INCLUSIVE EXPRESSED IN SHARES

	<i>Age, Years</i>	<i>Cal- ories^b</i>	<i>Pro- tein</i>	<i>Cal- cium</i>	<i>Iron</i>	<i>Vita- min A</i>	<i>Thia- mine</i>	<i>Ascor- bic Acid</i>	<i>Ribo- flavin</i>
Men	18	38.00	49	56	39	32	38	43	50
	19	38.00	49	56	39	32	38	43	50
	20	38.00	49	56	39	32	38	43	50
	21	38.00	49	56	39	32	38	43	50
	22	38.00	49	56	39	32	38	43	50
	23	36.00	44	50	36	32	36	38	40
	24	34.00	39	42	34	32	34	34	36
Women	18	24.00	37	52	39	32	24	34	38
	19	24.00	37	52	39	32	24	34	38
	20	24.00	37	52	39	32	24	34	38
	21	24.00	37	52	39	32	24	34	38
	22	24.00	37	52	39	32	24	34	38
	23	23.75	34	48	36	32	24	32	34
	24	23.50	30	42	34	32	24	31	30

^a Based on suggestions of the Food and Nutrition Board of the National Research Council, 1953.

^b Calories given are allowances for "standard" activity and should be adjusted for individual needs (see pages 53-56).

Table II. NUTRITIVE VALUES OF FOODS IN SHARES

One share of energy	= 100 calories
One share of protein	= 2.03 grams protein
One share of calcium	= 0.025 gram or 25 milligrams calcium
One share of iron	= 0.00038 gram or 0.38 milligram iron
One share of vitamin A	= 156 International Units vitamin A
One share of thiamine	= 0.05 milligram thiamine
One share of ascorbic acid	= 2.34 milligrams ascorbic acid
One share of riboflavin	= 0.05 milligram riboflavin

The values given are for raw edible portions of food unless otherwise stated.
A.P. means as purchased.
— means no appreciable amount.
A few values are stated within parentheses. This indicates that these values have been estimated.

Table II. NUTRITIVE VALUES OF FOODS IN SHARES

Food	Weight		Approximate Measure	Calo-ries	Shares						
	Gm.	Oz.			Pro-tein	Cal-cium	Iron	Vita-min A	Thia-mine	Ascorbic Acid	Ribo-flavin
Almonds, shelled	28	1.0	(A.P. 1.9 oz.)	170	2.6	2.9	3.2	0	1.4	Trace	3.8
	100	3.5	$\frac{1}{4}$ cup	597	9.2	10.2	11.6	0	5.0	Trace	13.4
	17	0.6	12-15 nuts	100	1.6	1.7	1.8	0	0.8	Trace	2.2
Apples, raw	28	1.0	(A.P. 1.1 oz.)	16	0.0	0.1	0.3	0.2	0.2	0.4	0.2
	100	3.5	1 small, 2 $\frac{1}{4}$ " diam.	58	0.1	0.2	0.8	0.6	0.8	2.1	0.6
	172	6.1	1 large, 3 $\frac{1}{4}$ " diam.	100	0.2	0.4	1.3	1.0	1.4	3.8	1.0
Apricots, canned in syrup (solids and liquid)	28	1.0		23	0.1	0.1	0.3	2.5	0.2	0.4	0.2
	100	3.5		80	0.3	0.4	0.8	8.7	0.4	1.7	0.4
	125	4.4	4 medium halves, 2 tbsp. juice	100	0.4	0.5	1.1	10.8	0.6	2.1	0.6
Apricots, dried, sulfured	28	1.0		74	0.7	1.0	3.7	13.5	0.0	1.3	1.0
	100	3.5	26 halves	262	2.6	3.4	12.9	47.6	0.2	5.1	3.2
	38	1.3	10 halves	100	1.0	1.3	5.0	18.1	0.0	2.1	1.2
Apricots, raw	28	1.0	(A.P. 1.1 oz.)	14	0.1	0.2	0.3	5.1	0.2	0.9	0.2
	100	3.5		51	0.5	0.6	1.3	17.9	0.6	3.0	1.0
	196	6.9	5 apricots	100	1.0	1.2	2.6	35.0	1.2	6.0	2.0
Asparagus, raw	28	1.0	(A.P. 1.3 oz.)	6	0.3	0.2	0.8	1.8	1.0	3.8	1.0
	100	3.5	12 stalks	21	1.1	0.8	2.4	6.4	3.2	14.1	3.8
	476	16.8	57 stalks, 5" long	100	5.2	4.0	11.3	30.5	15.2	67.1	18.0
Asparagus, cooked	175	6.2	1 cup, cut spears	36	2.1	1.3	4.7	11.7	4.6	17.1	6.0
Avocado, raw	28	1.0	(A.P. 1.3 oz.)	70	0.2	0.1	0.5	0.5	0.4	2.1	0.8
	100	3.5	$\frac{1}{4}$ pear	245	0.8	0.4	1.6	1.9	1.2	6.8	2.6
	41	1.4	$\frac{1}{8}$ pear, 3 $\frac{1}{4}$ " long	100	0.3	0.2	0.5	0.8	0.4	3.0	1.0
Bacon, broiled, medium fat	17	0.6	2 to 3 slices	100	2.0	0.2	1.3	(0)	1.6	0	1.0
Bacon, medium fat, uncooked	28	1.0	(A.P. 1.0 oz.)	179	1.3	0.2	0.5	(0)	2.2	0	0.6
	100	3.5	7 slices	630	4.5	0.5	2.1	(0)	7.6	0	2.4
	16	0.6	1 slice, 8 $\frac{1}{2}$ " long	100	0.7	0.1	0.3	(0)	1.2	0	0.4
Bananas, raw	28	1.0	(A.P. 1.5 oz.)	25	0.1	0.1	0.5	0.8	0.2	1.3	0.2
	100	3.5		88	0.6	0.3	1.6	2.8	0.8	4.3	1.0
	114	4.0	1 medium, 6 $\frac{3}{4}$ " long	100	0.7	0.4	1.8	3.1	1.0	4.7	1.2
Bean curd (see Soybean)											
Bean sprouts, mung	28	1.0	(A.P. 1.0 oz.)	7	0.4	0.3	0.5	0.0	0.4	1.7	0.6
	100	3.5	1 cup	23	1.4	1.2	1.8	0.1	1.4	6.4	1.8
	435	15.3	4 $\frac{1}{2}$ cups	100	6.2	5.0	9.2	0.3	6.0	27.8	7.8

Table II (Continued). NUTRITIVE VALUES OF FOODS IN SHARES

Food	Weight		Approximate Measure	Calo- ries	Shares						
	Gm.	Oz.			Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascorbic Acid	Ribo- flavin
Beans, baked, canned *	28 100 80	1.0 3.5 2.8	$\frac{1}{2}$ cup, scant $\frac{3}{8}$ cup	36 125 100	0.8 2.9 2.3	0.6 2.2 1.8	1.6 5.5 4.5	0.1 0.2 0.2	0.2 1.0 0.8	0.4 0.9 0.9	0.2 0.8 0.6
* With pork and molasses.											
Beans, dried,* uncooked	28 100 29	1.0 3.5 1.0	$\frac{1}{2}$ cup $\frac{1}{8}$ cup	96 343 100	3.2 11.4 3.3	1.8 6.5 1.9	5.0 18.2 5.3	0 0 0	3.4 12.2 3.6	0.4 0.9 0.4	1.2 4.6 1.4
* Navy, kidney, pinto, red, pea, black, others.											
Beans, Lima, dried, uncooked	28 100 30	1.0 3.5 1.1	$\frac{3}{8}$ cup $\frac{1}{8}$ cup	95 333 100	2.9 10.2 3.1	0.8 2.7 0.8	5.5 19.7 6.1	0 0 0	2.8 9.6 2.8	0.4 0.9 0.4	1.0 3.6 1.0
Beans, Lima, raw	28 100 78	1.0 3.5 2.8	(A.P. 2.5 oz.) $\frac{3}{8}$ cup $\frac{1}{2}$ cup	36 128 100	1.0 3.7 2.9	0.4 1.2 1.0	1.8 6.1 4.7	0.7 2.5 1.9	1.4 5.0 4.0	4.7 17.1 13.2	1.0 3.6 2.8
Beans, Lima	160	5.6	1 cup cooked	152	3.9	1.8	7.1	2.9	4.4	10.3	2.8
Beans, snap, string or green, raw	28 100 286	1.0 3.5 10.1	(A.P. 1.1 oz.) $\frac{1}{4}$ cup 2 $\frac{1}{8}$ cups, 1" pieces	10 35 100	0.3 1.2 3.4	0.7 2.6 7.4	0.8 2.9 8.2	1.5* 5.1* 14.7*	0.4 1.6 4.6	2.1 8.1 23.1	0.6 2.2 6.2
* Yellow about $\frac{1}{4}$ as much.											
Beans, snap	125	4.4	1 cup cooked	27	0.9	1.8	2.4	5.3	1.8	7.7	2.4
Beef, corned, canned, medium fat	28 100 46	1.0 3.5 1.6	1 piece, 3" \times 2" \times $\frac{1}{2}$ "	61 216 100	3.5 12.5 5.7	0.2 0.8 0.4	3.2 11.3 5.3	(0) (0) (0)	0.2 0.4 0.2	0 0 0	1.4 4.8 2.2
Beef, dried or chipped	28 100 49	1.0 3.5 1.7	4 thin slices, 4" \times 5"	58 203 100	4.8 16.9 8.3	0.2 0.8 0.4	3.7 13.4 6.6	(0) (0) (0)	0.6 2.2 1.0	0 0 0	1.2 4.4 2.2
Beef, round, lean, raw	28 100 62	1.0 3.5 2.2	(A.P. 1.0 oz.)* 1 piece, 2 $\frac{1}{2}$ " \times 1 $\frac{3}{4}$ " \times $\frac{3}{4}$ "	46 162 100	3.0 10.5 6.5	0.2 0.5 0.3	2.4 7.9 5.0	0.1 0.2 0.1	0.8 2.6 1.6	0 0 0	1.2 4.0 2.4
* Without bone.											
Beef, sirloin, roasted	28 100 34	1.0 3.5 1.2	2 slices 1 $\frac{1}{4}$ slices, 5" \times 2 $\frac{1}{2}$ " \times $\frac{1}{4}$ "	84 297 100	3.2 11.3 3.8	0.1 0.4 0.1	2.1 7.6 2.6	(0) (0) (0)	0.4 1.2 0.4	0 0 0	1.0 3.8 1.2

Table II (Continued). NUTRITIVE VALUES OF FOODS IN SHARES

Food	Weight		Approximate Measure	Calo- ries	Shares						
	Gm.	Oz.			Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascorbic Acid	Ribo- flavin
Beet greens, raw	28 100 370	1.0 3.5 13.0	(A.P. 1.3 oz.)	8 27 100	0.3 1.0 3.6	1.4* 4.7* 17.4*	2.4 8.4 31.1	12.2 42.9 158.9	0.4 1.6 6.0	4.3 14.5 53.8	1.0 3.6 13.4
* Availability doubtful because of oxalic acid present.											
Beet greens	145	5.1	1 cup cooked	39	1.4	6.8*	12.1	69.2	1.4	9.4	4.6
* Availability doubtful because of oxalic acid present.											
Beets, raw	28 100 238	1.0 3.5 8.4	(A.P. 1.3 oz.) 2 beets 5 beets, 2" diam.	12 42 100	0.2 0.8 1.9	0.3 1.1 2.6	0.8 2.6 6.3	0.0 0.1 0.3	0.2 0.4 1.0	1.3 4.3 10.3	0.2 1.0 2.4
Beets, cooked	165	5.8	1 cup, diced	68	0.8	1.4	3.2	0.2	0.6	4.7	1.4
Blackberries, raw	28 100 175	1.0 3.5 6.2	(A.P. 1.0 oz.) $\frac{8}{16}$ cup 54 berries, 1" long	16 57 100	0.1 0.6 1.0	0.4 1.3 2.2	0.8 2.4 4.2	0.4 1.3 2.2	0.2 0.8 1.4	2.6 9.0 15.8	0.2 0.8 1.4
Blueberries, raw	28 100 164	1.0 3.5 5.8	(A.P. 1.0 oz.) $\frac{3}{4}$ cup 1 $\frac{1}{4}$ cups	17 61 100	0.1 0.3 0.5	0.2 0.6 1.0	0.5 2.1 3.4	0.5 1.8 2.9	(0.2) (0.4) (0.6)	2.1 6.8 11.1	(0.2) (0.4) (0.6)
Bluefish (see Fish)											
Bran, wheat (100% bran)	28 100 44	1.0 3.5 1.6	1 $\frac{1}{2}$ cups $\frac{3}{4}$ cup	64 225 100	1.7 5.9 2.6	1.1 3.8 1.6	7.6 27.1 11.8	(0) (0) (0)	2.2 7.4 3.2	0 0 0	2.2 7.8 3.4
Bread, Boston brown, enriched	28 100 46	1.0 3.5 1.6	1 slice, 3" diam., $\frac{3}{4}$ " thick	62 219 100	0.7 2.4 1.1	2.1 7.4 3.4	2.1* 7.6* 3.4*	0.3 0.9 0.4	0.8* 2.6* 1.2*	0 0 0	1.0* 3.4* 1.6*
* For unenriched per 100 gm., iron 6.3, thiamine 1.6, and riboflavin 2.4.											
Bread, cracked wheat, enriched	28 100 39	1.0 3.5 1.4	4 $\frac{3}{4}$ slices 1 $\frac{1}{4}$ slices, 4" \times 3 $\frac{3}{4}$ " \times $\frac{1}{2}$ "	74 259 100	1.2 4.2 1.6	1.0 3.3 1.3	1.6* 5.3* 2.1*	0 0 0	1.4* 5.0* 2.0*	0 0 0	1.0* 3.8* 1.4*
* For unenriched per 100 gm., iron 2.6, thiamine 2.2, and riboflavin 2.0.											
Bread, rye and wheat	28 100 41	1.0 3.5 1.4	3 $\frac{1}{2}$ slices 1 $\frac{1}{4}$ slices, 3 $\frac{1}{2}$ " \times 4" \times $\frac{1}{2}$ "	69 244 100	1.3 4.5 1.8	0.8 2.5 1.2	1.3 4.2 1.8	0 0 0	0.8 2.8 1.2	0 0 0	0.4 1.6 0.6

Table II (Continued). NUTRITIVE VALUES OF FOODS IN SHARES

Food	Weight		Approximate Measure	Calo- ries	Shares						
	Gm.	Oz.			Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascorbic Acid	Ribo- flavin
Bread,* white, enriched	28 100 36 23	1.0 3.5 1.3 0.8	4½ slices 1¾ slices 1 slice, 4" × 3¾" × ½"	78 275 100 63	1.2 4.2 1.5 1.0	0.9 3.2 1.1 0.7	1.3 4.7 1.6 1.1	0 0 0 0	1.4 4.8 1.8 1.2	0 0 0 0	0.8 3.0 1.0 0.8
* 4% nonfat milk solids.											
Bread,* white, unenriched	28 100 36	1.0 3.5 1.3	4½ slices 1¾ slices, 4" × 3¾" × ½"	78 275 100	1.2 4.2 1.5	0.9 3.2 1.1	0.5 1.6 0.5	0 0 0	0.2 1.0 0.4	0 0 0	0.6 2.2 0.8
* 4% nonfat milk solids.											
Bread, white, raisin, enriched	28 100 35	1.0 3.5 1.2	3 slices 1 slice, 3¾" × 3½" × ½"	81 284 100	1.0 3.5 1.2	0.9 3.2 1.1	1.3* 4.7* 1.6*	0.0 0.1 0.0	1.4* 4.8* 1.6*	0 0 0	0.8* 3.0* 1.0*
* For unenriched per 100 gm., iron 3.4, thiamine 1.4, and riboflavin 2.2.											
Bread, whole wheat	28 100 42	1.0 3.5 1.5	1 slice 3½ slices 1½ slices, 3" × 3¾" × ½"	68 240 100	1.3 4.6 1.9	1.1 3.8 1.6	1.6 5.8 2.4	0 0 0	1.8 6.0 2.6	0 0 0	0.8 2.6 1.0
Broccoli, raw	28 100 345	1.0 3.5 12.2	(A.P. 1.6 oz.) 4 stalks, 5" long, stem 1½" thick	8 29 100	0.4 1.6 5.6	1.5 5.2 18.0	1.1 3.4 11.8	10.9 38.5 132.7	0.6 2.0 7.0	14.5 50.4 173.9	1.2 4.2 14.4
Broccoli	150	5.3	1 cup cooked	44	2.5	7.8	5.3	32.7	2.0	47.4	4.4
Brussels sprouts, raw	28 100 213	1.0 3.5 7.5	(A.P. 1.3 oz.) 7 sprouts 15 sprouts, 1½" diam.	13 47 100	0.6 2.2 4.6	0.4 1.4 2.9	1.1 3.4 7.4	0.7 2.6 5.5	0.4 1.6 3.4	11.5 40.2 85.5	1.0 3.2 6.8
Brussels sprouts	130	4.6	1 cup cooked	60	2.8	1.8	4.5	3.3	1.0	26.1	3.2
Butter	28 100 14	1.0 3.5 0.5	½ cup, scant 1 tbsp.	203 716 100	0.1 0.3 0.0	0.2 0.8 0.1	0 0 0	6.0* 21.2* 3.0*	Trace Trace Trace	0 0 0	0.0 0.2 0.0
* Based on year-round average of 15,000 I.U. per pound (96.2 shares).											
Buttermilk	(see Milk)										

Table II (Continued). NUTRITIVE VALUES OF FOODS IN SHARES

Food	Weight		Approximate Measure	Calo-ries	Shares							
	Gm.	Oz.			Calo-ries	Pro-tein	Cal-cium	Iron	Vita-min A	Thia-mine	Ascorbic Acid	Ribo-flavin
Cabbage, Chinese, raw	28 100 714	1.0 3.5 25.2	(A.P. 1.4 oz.) ¾ cup, shredded ¾ medium head	4 14 100	0.04 0.14 1.00	0.1 0.6 4.2	0.5 1.7 12.3	0.8 2.4 16.8	0.5 1.7 11.9	0.2 0.6 4.2	3.8 13.2 94.4	0.2 0.8 5.8
Cabbage, headed, raw	28 100 417	1.0 3.5 14.7	(A.P. 1.4 oz.) 1½ cups, shredded 4½ cups, chopped	7 24 100	0.07 0.24 1.00	0.2 0.7 2.9	0.5 1.8 7.7	0.3 1.3 5.5	0.1* 0.5* 2.1*	0.4 1.2 5.0	6.0 21.4 89.3	0.2 1.0 4.2
* Loose leaf 10 times as much.												
Cabbage	170	6.0	1 cup cooked	40	0.40	1.2	3.1	2.1	1.0	1.6	22.6	1.6
Cantaloupes, raw	28 100 500	1.0 3.5 17.6	(A.P. 2.1 oz.) ¼ melon 1½ melons, 5" diam.	6 20 100	0.06 0.20 1.00	0.1 0.3 1.5	0.2 0.7 3.4	0.3 1.1 5.3	6.2* 21.9* 109.6*	0.2 1.0 5.0	3.8 14.1 70.5	0.2 0.8 4.0
* Based on dark yellow varieties.												
Carrots, raw	28 100 238	1.0 3.5 8.4	(A.P. 1.6 oz.) ¾ cup, ½" cubes 5 medium, 5" long	12 42 100	0.12 0.42 1.00	0.1 0.6 1.4	0.4 1.6 3.7	0.5 2.1 5.0	21.8 76.9 183.1	0.4 1.2 2.8	0.9 2.6 6.0	0.4 1.2 2.8
Carrots, cooked	145	5.1	1 cup, cubed	44	0.44	0.4	1.5	2.4	116.2	1.4	2.6	1.4
Cashew nuts	28 100 17	1.0 3.5 0.6	¾ cup 4 to 5 nuts	164 578 100	1.64 5.78 1.00	2.6 9.1 1.5	0.5 1.8 0.3	3.7 13.2 2.4	— — —	3.6 12.6 2.2	0 0 0	1.0 3.8 0.6
Cassava (see Tapioca)												
Cauliflower, raw	28 100 400	1.0 3.5 14.1	(A.P. 2.2 oz.) 1 cup, small pieces 1 head, 4¾" diam.	7 25 100	0.07 0.25 1.00	0.3 1.2 4.7	0.2 0.9 3.5	0.8 2.9 11.6	0.2 0.6 2.3	0.6 2.2 8.8	8.5 29.5 117.9	0.6 2.0 8.0
Cauliflower	120	4.2	1 cup cooked	30	0.30	1.4	1.0	3.4	0.7	1.4	14.5	2.0
Celery, bleached	28 100 556	1.0 3.5 19.6	(A.P. 1.6 oz.) ¾ cup 4½ cups, ¾" pieces	5 18 100	0.05 0.18 1.00	0.2 0.6 3.5	0.6 2.0 11.1	0.3 1.3 7.4	0 0 0	0.2 1.0 5.6	0.9 3.0 16.7	0.2 0.8 4.4
Chard, Swiss, raw	28 100 476	1.0 3.5 16.8	(A.P. 1.2 oz.)	6 21 100	0.06 0.21 1.00	0.2 0.7 3.3	1.2* 4.2* 20.0*	1.8 6.6 31.3	5.1 17.9 85.4	0.4 1.2 5.8	4.7 16.2 77.3	0.4 1.4 6.6
* Availability doubtful.												
Chard	145	5.1	1 cup cooked	30	0.30	1.0	6.1*	9.5	28.9	1.2	10.7	1.8
* Availability doubtful.												
Cheese, bleu	(see Cheese, Roquefort)											

Table II (Continued). NUTRITIVE VALUES OF FOODS IN SHARES

Food	Weight		Approximate Measure	Calo- ries	Shares						
	Gm.	Oz.			Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascorbic Acid	Ribo- flavin
Cheese, Cheddar	28	1.0	1" cube	113	3.5	9.9	0.8	2.6	0.2	(0)	2.4
	100	3.5	4 slices, 3½" × 3½" × ½"	398	12.3	34.9	2.6	9.0	0.4	(0)	8.4
	25	0.9	½ cup, scant, grated	100	3.1	8.7	0.8	2.2	0.2	(0)	2.2
Cheese, cottage (skim milk)	28	1.0		27	2.7	1.1	0.3	(0.0)	0.2	0	1.8
	100	3.5	5½ tbsp.	95	9.6	3.8	0.8	(0.1)	0.4	0	6.2
	105	3.7	½ cup, scant	100	10.1	4.0	0.8	(0.1)	0.4	0	6.6
Cheese, cream	28	1.0		105	1.3	0.8	0.3	(2.6)	(0.0)	(0)	1.2
	100	3.5	7 tbsp.	371	4.4	2.7	0.5	(9.3)	(0.2)	(0)	4.4
	27	1.0	2 tbsp.	100	1.2	0.7	0.3	(2.5)	(0.0)	(0)	1.2
Cheese, Parmesan	28	1.0		112	5.0	13.2	0.3	2.5	0.2	0	4.2
	100	3.5	1½ cups	393	17.7	46.4	1.1	8.7	0.6	0	14.6
	25	0.9	¾ cup	100	4.4	11.6	0.3	2.2	0.2	0	3.6
Cheese, Roquefort (blue mold, domestic)	28	1.0		105	3.0	3.6	0.8	2.3	0.2	0	3.4
	100	3.5	6¾ tbsp.	368	10.6	12.6	2.6	7.9	0.6	0	12.2
	27	1.0	1½ tbsp.	100	2.9	3.4	0.8	2.1	0.2	0	3.2
Cheese, Swiss, processed	28	1.0		105	3.8	10.5	0.8	2.6	0.0	0	2.2
	100	3.5		370	13.5	37.0	2.4	9.3	0.2	0	8.0
	27	1.0	1 slice, 3½" × 3½" × ½"	100	3.6	10.0	0.5	2.5	0.0	0	2.2
Cherries, canned in syrup	28	1.0		21	0.1	0.1	0.3	(0.8)	0.2	0.4	0.2
	100	3.5		75	0.3	0.4	0.8	(2.8)	0.6	1.3	0.4
	133	4.7	½ cup	100	0.4	0.6	1.1	(3.7)	0.8	1.7	0.6
Cherries, red, sour, pitted, canned	28	1.0		14	0.1	0.1	(0.3)	1.3	0.2	0.9	0.2
	100	3.5	¾ cup	48	0.4	0.4	(0.8)	4.6	0.6	2.6	0.4
	208	7.3	¾ cup	100	0.8	0.9	(1.6)	9.6	1.2	5.1	0.8
Cherries, sweet, raw	28	1.0	(A.P. 1.1 oz.)	20	0.1	0.2	0.3	0.6	0.2	1.3	(0.2)
	100	3.5	15 cherries	72	0.5	0.7	1.3	2.0	1.0	3.8	(0.4)
	139	4.9	22 cherries, ¾" diam.	100	0.7	1.0	1.8	2.8	1.4	5.6	(0.6)
Chicken, broilers (flesh only), raw	28	1.0	(A.P. 1.3 oz.)	43	2.8	0.2	1.0	(0)	0.4	0	1.0
	100	3.5	½ medium broiler	151	10.0	0.6	3.9	(0)	1.6	0	3.2
	66	2.3		100	6.6	0.4	2.6	(0)	1.0	0	2.2
Chicken, canned, boned	28	1.0		57	4.2	0.2	1.3	(0)	0.2	(0)	1.0
	100	3.5		199	14.7	0.6	4.7	(0)	0.8	(0)	3.2
	50	1.8	¼ cup	100	7.3	0.3	2.4	(0)	0.4	(0)	1.6

Table II (Continued). NUTRITIVE VALUES OF FOODS IN SHARES

Food	Weight		Approximate Measure	Calo-ries	Shares						
	Gm.	Oz.			Pro-tein	Cal-cium	Iron	Vita-min A	Thia-mine	Ascorbic Acid	Ribo-flavin
Chicken, roasters (flesh only), raw	28 100 50	1.0 3.5 1.8	(A.P. 1.3 oz.) 3 slices 1½ slices, 3½" × 2½" × ¾"	57 200 100	3.8 10.0 5.0	0.2 0.6 0.3	1.1 3.9 2.1	(0) (0) (0)	0.4 1.6 0.8	(0) (0) (0)	1.0 3.2 1.6
Chickpeas (see Garbanzos)											
Chocolate, un-sweetened or bitter	28 100 20	1.0 3.5 0.7	1 square 3½ squares ¾ square	140 492 100	(0.8) (2.7) (0.5)	1.1* 3.9* 0.8*	3.2 11.1 2.1	0.1 0.4 0.1	0.2 1.0 0.2	(0) (0) (0)	1.4 4.8 1.0
* Availability doubtful.											
Clams, long or round, raw	28 100 123	1.0 3.5 4.3	½ cup 5 to 6 clams	23 81 100	1.8 6.3 7.7	1.1 3.8 4.7	(5.3) (18.4) (22.6)	0.2 0.7 0.9	0.6 2.0 2.4	- - -	1.0 3.6 4.4
Cocoa powder	28 100 36	1.0 3.5 1.3	½ cup 4¾ tbsp.	80 281 100	1.3 4.4 1.6	1.4* 5.0* 1.8*	8.7 30.5 11.1	(0.1) (0.2) (0.1)	0.6 2.4 0.8	0 0 0	2.2 7.8 2.8
* Availability doubtful.											
Cod (see Fish)											
Cod liver oil	11	0.4	1 tbsp.	100	0	0	0	59.9*	0	0	0
* U.S.P. Standard; for various brands, see statement on container.											
Collards, raw	28 100 250	1.0 3.5 8.8	(A.P. 2.2 oz.)	11 40 100	0.5 1.9 4.8	2.8 10.0 24.9	1.3 4.2 10.5	18.2* 64.1* 160.3*	1.2 4.0 10.0	7.7 27.8 69.6	1.4 5.0 12.6
* Fully green leaves.											
Collards	190	6.7	1 cup cooked	76	3.6	18.9	7.9	92.9	3.0	35.9	9.2
Corn, canned, drained solids	28 100 118	1.0 3.5 4.2	½ cup ¾ cup	24 85 100	0.4 1.3 1.6	0.0 0.2 0.2	0.5 1.6 1.8	0.4* 1.5* 1.7*	0.2 0.6 0.8	0.4 2.1 2.6	0.4 1.2 1.4
* Yellow; only a trace in white.											
Corn, canned, solids and liquids	256	9.0	1 cup	170*	2.5	0.4	3.4	3.3**	1.4	6.0	2.6
* For cream style, 208; changes in other nutrients insignificant.											
** Yellow; only a trace in white.											

Table II (Continued). NUTRITIVE VALUES OF FOODS IN SHARES

Food	Weight		Approximate Measure	Calo- ries	Shares							
	Gm.	Oz.			Calo- ries	Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascorbic Acid	Ribo- flavin
Corn, sweet, on cob, cooked * Yellow; only a trace in white.	168	5.9	1 ear, 6" long	100	1.00	1.6	0.2	1.8	3.0 *	2.6	4.3	2.4
Corn flakes with added iron and thiamine	28 100 26	1.0 3.5 0.9	4½ cups 1¼ cups	109 385 100	1.09 3.85 1.00	1.1 4.0 1.0	0.1 0.4 0.1	1.6 5.8 1.6	(0) (0) (0)	2.4 8.6 2.2	0 0 0	0.6 2.0 0.6
Corn grits (see Hominy)												
Corn meal, deger- minated, enriched * Yellow; only a trace in white.	100 28 238	3.5 1.0 8.4	¾ cup uncooked 3 tbsp. uncooked 1 cup cooked	363 100 119	3.63 1.00 1.19	3.9 1.1 1.3	0.2 0.1 0.1	7.6 2.1 2.6	1.9 * 0.5 * 0.6 *	8.8 2.4 2.8	0 0 (0)	5.2 1.4 1.8
Corn meal, deger- minated, unenriched * Yellow; only a trace in white.	100 28 238	3.5 1.0 8.4	¾ cup uncooked 3 tbsp. uncooked 1 cup cooked	363 100 119	3.63 1.00 1.19	3.9 1.1 1.3	0.2 0.1 0.1	2.9 0.8 1.3	1.9 * 0.5 * 0.6 *	3.2 0.8 0.8	0 0 (0)	1.6 0.4 0.4
Crab meat, canned	28 100 96	1.0 3.5 3.4	⅔ cup	30 104 100	0.30 1.04 1.00	2.3 8.3 8.0	0.5 1.8 1.7	0.8 2.4 2.4	— — —	1.4 4.6 4.4	0 0 0	0.8 3.0 2.8
Crackers, Graham or whole wheat	28 100 25	1.0 3.5 0.9	10½ crackers 2½ crackers, 2½" × 2¾"	112 393 100	1.12 3.93 1.00	1.1 3.9 1.0	0.2 0.8 0.2	1.3 5.0 1.3	(0) (0) (0)	1.8 6.0 1.6	0 0 0	0.6 2.4 0.6
Crackers, oyster	28 100	1.0 3.5	1 cup 100 crackers	119 430	1.19 4.30	1.3 4.9	0.2 0.8	0.8 2.6	(0) (0)	0.4 2.0	(0) (0)	0.2 0.8
Crackers, saltines	28 100 23	1.0 3.5 0.8	25 crackers 6 crackers, 2" square	122 431 100	1.22 4.31 1.00	1.3 4.5 1.0	0.2 0.8 0.2	0.8 2.6 0.5	(0) (0) (0)	0.4 1.2 0.2	(0) (0) (0)	0.2 0.8 0.2
Cranberries, raw	28 100 208	1.0 3.5 7.3	(A.P. 1.0 oz.) ¾ cup 1⅞ cups	14 48 100	0.14 0.48 1.00	0.0 0.2 0.4	0.2 0.6 1.2	0.5 1.6 3.2	0.1 0.3 0.5	(0.2) (0.6) (1.2)	1.3 5.1 10.7	(0.2) (0.8) (1.6)
Cranberry sauce (whole), canned	28 100 51	1.0 3.5 1.8	¾ cup 3 tbsp.	56 198 100	0.56 1.98 1.00	0.0 0.0 0.0	(0.1) (0.3) (0.2)	(0.3) (0.8) (0.5)	0.1 0.2 0.1	(0.2) (0.4) (0.2)	0.4 0.9 0.4	(0.2) (0.4) (0.2)
Cream, heavy, whipping	28 100 30	1.0 3.5 1.1	¾ cup 2 tbsp.	94 330 100	0.94 3.30 1.00	0.3 1.1 0.3	0.9 3.1 0.9	0.0 0.0 0.0	3.6 12.6 3.8	0.2 0.4 0.2	0.0 0.4 0.0	0.6 2.2 0.6

Table II (Continued). NUTRITIVE VALUES OF FOODS IN SHARES

Food	Weight		Approximate Measure	Calo- ries	Shares						
	Gm.	Oz.			Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascorbic Acid	Ribo- flavin
Cream, light, coffee	28 100 49	1.0 3.5 1.7	$\frac{1}{8}$ cup 3 tbsp.	58 204 100	0.4 1.4 0.7	1.1 3.9 1.9	0.0 0.3 0.0	1.5 5.3 2.6	0.2 0.6 0.2	0.0 0.4 0.0	0.8 2.8 1.4
Cucumbers, raw	28 100 833	1.0 3.5 29.4	(A.P. 1.4 oz.) 12 slices, $\frac{1}{8}$ " thick 3 cucumbers, $7\frac{1}{2}$ " long, 2" diam.	3 12 100	0.1 0.3 2.9	0.1 0.4 3.3	0.3* 0.8* 6.6*	0* 0* 0*	0.2 0.8 6.6	0.9 3.4 28.6	0.6 2.4 20.0
* For pared cucumbers; unpared 3.2 iron and 1.7 vitamin A per 100 gm.											
Dandelion greens, raw	28 100 227	1.0 3.5 8.0	(A.P. 1.9 oz.) 5 $\frac{1}{4}$ cups	12 44 100	0.4 1.3 3.0	1.7 6.0 13.6	2.4 8.2 18.4	(18.2) (64.1) (145.5)	1.0 3.8 8.6	3.0 9.8 22.2	0.8 2.8 6.4
Dandelion greens	140	4.9	1 cup cooked	62	1.9	8.4	11.3	(137.4)	3.8	9.8	3.4
Dasheen (see Yautia)											
Dates, "fresh" and dried, stoned	28 100 35	1.0 3.5 1.2	14 dates 5 dates	81 284 100	0.3 1.1 0.4	0.8 2.9 1.0	1.6 5.5 1.8	0.3 1.2 0.4	0.4 1.6 0.6	0 0 0	0.2 1.0 0.4
Eggplant, raw	28 100 417	1.0 3.5 14.7	(A.P. 1.1 oz.) 7 slices, 4" diam., $\frac{1}{4}$ " thick	7 24 100	0.1 0.5 2.3	0.2 0.6 2.5	0.3 1.1 4.5	0.1 0.4 1.6	0.4 1.4 5.8	0.9 3.0 12.4	0.4 1.2 5.0
Eggs, whole, raw	28 100 62	1.0 3.5 2.2	(A.P. 1.1 oz.) 1 $\frac{1}{4}$ eggs	46 162 100	1.8 6.3 3.9	0.6 2.2 1.3	2.1 7.1 4.5	2.7 9.6 6.0	0.6 2.0 1.2	0 0 0	2.2 7.4 4.6
Eggs, whole, cooked	53	1.9	1 egg in shell	75	3.0	1.0	3.4	3.5	0.8	0	2.6
Eggs, white only, raw	28 100 200	1.0 3.5 7.1	3 $\frac{1}{4}$ whites 6 $\frac{1}{2}$ whites	14 50 100	1.5 5.3 10.6	0.1 0.4 0.9	0.0 0.3 0.5	(0) (0) (0)	0 0 0	0 0 0	1.4 4.6 9.2
Eggs, yolk only, raw	100 28	3.5 1.0	6 yolks, medium 2 yolks, small	361 100	8.0 2.3	6.3 1.8	19.0 5.3	24.0 6.7	6.0 1.6	0 0	9.0 2.6
Escarole and endive, raw	28 100 500	1.0 3.5 17.6	(A.P. 1.9 oz.)	6 20 100	0.2 0.8 3.9	0.9 3.2 15.8	1.3 4.5 22.4	(18.2)* (64.1)* (320.5)*	0.4 1.6 8.0	1.3 4.7 23.5	1.8 6.6 33.0
* Bleached varieties, little or no vitamin A value.											

Table II (Continued). NUTRITIVE VALUES OF FOODS IN SHARES

Food	Weight		Approximate Measure	Calo- ries	Shares						
	Gm.	Oz.			Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascorbic Acid	Ribo- flavin
Farina, dark	(see Wheat meal)										
Farina, white, enriched	28 100 27 240	1.0 3.5 1.0 8.5	$\frac{1}{8}$ cup uncooked $2\frac{1}{8}$ tbsp. 1 cup cooked	105 370 100 104	1.5 5.4 1.4 1.5	0.2 0.8 0.2 0.3	1.0 3.4 1.1 1.3	(0) (0) (0) (0)	2.2 7.4 2.0 2.0	0 0 0 0	1.4 5.2 1.4 1.4
Farina, white, unenriched	28 100 27 240	1.0 3.5 1.0 8.5	$\frac{1}{8}$ cup uncooked $2\frac{1}{8}$ tbsp. uncooked 1 cup cooked	105 370 100 104	1.5 5.4 1.4 1.5	0.2 0.8 0.2 0.3	0.8 2.6 0.8 0.5	(0) (0) (0) (0)	0.4 1.2 0.4 0.2	0 0 0 0	0.4 1.2 0.4 0.4
Figs, dried	28 100 37	1.0 3.5 1.3	6 medium 2 medium	77 270 100	0.5 2.0 0.7	2.1 7.4 2.8	2.1 7.6 2.9	0.1 0.4 0.2	0.8 2.6 1.0	0 0 0	0.6 2.2 0.8
Figs, raw	28 100 127	1.0 3.5 4.5	(A.P. 1.0 oz.) $2\frac{1}{2}$ small $3\frac{1}{2}$ small, $1\frac{1}{2}$ " diam.	22 79 100	0.2 0.7 0.9	0.6 2.2 2.8	0.5 1.6 2.1	0.1 0.5 0.6	0.4 1.6 2.0	0.4 0.9 1.3	0.4 1.2 1.6
Fish, bluefish, raw	28 100	1.0 3.5	(A.P. 2.0 oz.) 1 piece, $3'' \times 2\frac{1}{2}'' \times 1''$	35 124	2.9 10.1	0.3 0.9	0.5 1.6	- -	0.4 1.4	(0.4) (0.9)	0.4 1.4
Fish, bluefish	50	1.8	1 piece, $3\frac{1}{2}'' \times 1'' \times \frac{1}{2}''$, fried	102	5.6	0.4	0.8	-	1.0	-	1.0
Fish, cod, raw	28 100 135	1.0 3.5 4.8	(A.P. 1.4 oz.) 1 piece, $4'' \times 2\frac{1}{2}'' \times 1''$	21 74 100	2.3 8.1 11.0	0.1 0.4 0.6	0.8 2.4 3.2	0 0 0	0.4 1.2 1.6	0.4 0.9 1.3	0.6 1.8 2.4
Fish, cod, salted	28 100 77	1.0 3.5 2.7	 	37 130 100	4.0 14.3 11.0	0.1 0.3 0.2	0.3 0.8 0.5	0 0 0	0.2 0.4 0.4	0 0 0	0.4 1.4 1.0
Fish, flounder, raw	28 100 147	1.0 3.5 5.2	(A.P. 2.5 oz.) 1 piece, $4'' \times 2\frac{1}{2}'' \times 1''$	19 68 100	2.1 7.3 10.8	0.4 1.6 2.4	0.5 2.1 3.2	- - -	0.4 1.2 1.8	- - -	0.2 1.0 1.4
Fish, haddock, raw	28 100	1.0 3.5	(A.P. 2.1 oz.) 1 section, $1\frac{1}{4}''$ on back	22 79	2.6 9.0	0.3 0.9	0.5 1.8	0.0 0.0	0.2 1.0	0 0	0.4 1.6
Fish, haddock	63	2.2	1 piece, $3'' \times 2\frac{1}{2}'' \times \frac{1}{2}''$, fried	100	5.8	0.4	1.1	-	0.6	-	1.2

Table II (Continued). NUTRITIVE VALUES OF FOODS IN SHARES

Food	Weight		Approximate Measure	Calo-ries	Shares						
	Gm.	Oz.			Pro-tein	Cal-cium	Iron	Vita-min A	Thia-mine	Ascorbic Acid	Ribo-flavin
Fish, halibut steak, raw	28 100	1.0 3.5	(A.P. 1.2 oz.) 1 piece, 3" × 1½" × 1"	36 126	2.6 9.2	0.2 0.5	0.5 1.8	0.8 2.8	0.4 1.4	0 0	0.4 1.2
Fish, halibut	55	1.9	1 piece, 3" × 1¾" × ½", broiled	100	7.1	0.3	1.1	—	0.6	—	0.8
Fish, mackerel, raw	28 100	1.0 3.5	(A.P. 1.9 oz.) 1 section, 4½" on back	53 188	2.6 9.2	0.1 0.4	0.8 2.6	0.8 2.9	0.8 3.0	—	2.0 7.0
Fish, salmon, canned	28 100 49	1.0 3.5 1.7	¾ cup ¾ cup	58 203 100	2.8 9.7 4.8	1.8 6.2 3.0	0.8 2.4 1.1	0.4 1.5 0.7	0.2 0.6 0.2	0 0 0	0.8 2.8 1.4
Fish, salmon, raw	28 100	1.0 3.5	(A.P. 1.1 oz.) 2 slices, 3" × 2" × ¾"	63 220	2.8 9.9	0.3 0.8	0.8 2.9	0.6 2.0	1.0 3.3	1.3 3.8	1.1 3.7
Fish, salmon	60	2.1	1 slice, 3" × 2" × ½", broiled	100	4.5	0.4	1.3	0.9	1.5	1.7	1.6
Fish, sardines, drained solids	28 100 47	1.0 3.5 1.7	10 sardines 4 sardines, 3" long	61 214 100	3.6 12.7 6.0	4.4 15.4 7.2	2.6 9.2 4.2	0.4 1.4 0.7	0.2 0.4 0.2	0 0 0	1.0 3.4 1.6
Fish, shad, raw	28 100 60	1.0 3.5 2.1	(A.P. 2.1 oz.) 1 section, 2½" long	48 168 100	2.6 9.2 5.5	0.2 0.8 0.5	0.3 1.3 0.8	0.2 0.8 0.5	0.6 1.8 1.0	0 0 0	1.4 4.8 2.8
Fish, swordfish, raw	28 100	1.0 3.5	(A.P. 1.0 oz.) 1 slice, 3" × 3" × ¾"	34 118	2.7 9.5	0.2 0.8	0.8 2.4	2.9 10.1	0.2 1.0	— —	0.2 1.0
Fish, swordfish	56	2.0	1 slice, 3" × 1½" × ½", broiled	100	7.6	0.4	1.6	8.3	0.6	(0)	0.6
Fish, tuna, canned, drained	28 100 51	1.0 3.5 1.8	¾ cup ¾ cup	56 198 100	4.0 14.3 7.3	0.4 1.4 0.7	1.3 4.5 2.4	0.1 0.4 0.2	0.2 0.8 0.4	0 0 0	0.8 2.6 1.4
Flounder	(see Fish)										
Flour, rye, light	100 28	3.5 1.0	¾ cup 3 tbsp.	357 100	4.6 1.3	0.9 0.2	3.4 1.1	(0) (0)	3.0 0.8	0 0	1.4 0.4
Flour, wheat, 80% extraction	100 28	3.5 1.0	¾ cup	359 100	5.9 1.7	1.0 0.3	3.4 1.1	(0) (0)	5.2 1.4	(0) (0)	1.4 0.4
Flour, wheat, white, enriched	28 100 27	1.0 3.5 1.0	¾ cup, sifted 4 tbsp., sifted	103 364 100	1.5 5.2 1.4	0.2 0.6 0.2	2.1 7.6 2.1	0 0 0	2.4 8.8 2.4	0 0 0	1.4 5.2 1.4

Table II (Continued). NUTRITIVE VALUES OF FOODS IN SHARES

Food	Weight		Approximate Measure	Calo- ries	Shares						
	Gm.	Oz.			Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascorbic Acid	Ribo- flavin
Ham, smoked, medium fat	200	7.0	1 slice cooked, 5½" diam., ⅝" thick	800	22.7	0.8	15.3	(0)	21.6	0	8.4
Hamburger (see Beef, round)											
Hominy (corn grits), enriched	100 28 242	3.5 1.0 8.5	3 tbsp. 1 cup cooked	362 100 122	4.3 1.2 1.4	0.2 0.0 0.1	7.6 2.1 1.8	1.9* 0.5* 0.6*	8.8 2.4 2.2	0 0 0	5.2 1.4 1.6
* Yellow; only a trace in white.											
Hominy (corn grits), unenriched	100 28	3.5 1.0	3 tbsp.	362 100	4.3 1.2	0.2 0.0	2.6 0.8	1.9* 0.5*	2.6 0.8	0 0	0.8 0.2
* Yellow; only a trace in white.											
Honey, strained	28 100 34	1.0 3.5 1.2	⅔ cup 1 tbsp., rounded	83 294 100	0.0 0.1 0.0	0.0 0.2 0.1	0.8 2.4 0.8	(0) (0) (0)	Trace Trace Trace	0.4 1.7 0.4	0.2 0.8 0.2
Honeydew melon, raw	28 100 313	1.0 3.5 11.0	(A.P. 1.6 oz.) ⅔ cup, balls 2 wedges, 2" × 7"	9 32 100	0.0 0.2 0.8	(0.2) (0.7) (2.1)	(0.3) (1.1) (3.4)	0.1 0.3 0.8	0.2 1.0 3.2	3.0 9.8 30.8	0.2 0.6 1.8
Ice cream, plain	28 100 48	1.0 3.5 1.7	⅔ cup	59 207 100	0.5 2.0 0.9	1.4 4.9 2.4	0.0 0.3 0.0	0.9 3.3 1.6	0.2 0.8 0.4	0.0 0.4 0.0	1.0 3.8 1.8
Jams, marmalades, etc.	28 100 36	1.0 3.5 1.3	5 tbsp. 1⅔ tbsp.	79 278 100	0.0 0.2 0.1	0.1 0.5 0.2	0.3 0.8 0.3	0.0 0.1 0.0	0.2 0.4 0.2	0.9 2.6 0.9	0.2 0.4 0.2
Jellies	28 100 40	1.0 3.5 1.4	5 tbsp. 2 tbsp.	72 252 100	0.0 0.1 0.0	(0.1) (0.5) (0.2)	(0.3) (0.8) (0.3)	(0.0) (0.1) (0.0)	(0.2) (0.4) (0.2)	0.4 1.7 0.9	(0.2) (0.4) (0.2)
Kale, raw	28 100 250	1.0 3.5 8.8	(A.P. 1.6 oz.) 5⅔ cups	11 40 100	0.5 1.9 4.8	2.6 9.0 22.5	1.8 6.6 16.6	(18.2) (64.1) (160.3)	1.0 3.2 8.0	14.5 50.4 126.1	1.8 6.6 16.6
Kale	110	3.9	1 cup cooked	45	2.1	9.9	6.3	59.1	1.6	23.9	5.0
Kidney, beef, raw	28 100 71	1.0 3.5 2.5	(A.P. 1.0 oz.) ⅔ cup, cubed ⅔ cup, cubed	40 141 100	2.1 7.4 5.3	0.1 0.4 0.2	5.8 20.8 14.7	2.1 7.4 5.2	2.2 7.4 5.2	1.7 5.6 3.8	14.4 51.0 36.2

Table II (Continued). NUTRITIVE VALUES OF FOODS IN SHARES

Food	Weight		Approximate Measure	Calo- ries	Shares							
	Gm.	Oz.			Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascorbic Acid	Ribo- flavin	
Kohlrabi, raw	28 100 333	1.0 3.5 11.7	(A.P. 1.9 oz.) ¾ cup 2⅔ cups, ½" cubes	9 30 100	0.09 0.30 1.00	0.3 1.0 3.4	0.5 1.8 6.1	0.5 1.6 5.3	Trace Trace Trace	0.4 1.2 4.0	7.3 25.6 85.5	0.2 1.0 3.4
Kohlrabi	155	5.5	1 cup cooked	47	0.47	1.6	2.8	2.4	Trace	1.2	24.4	1.2
Lamb, leg, roasted	28 100 36	1.0 3.5 1.3	1 slice, 3½" × 3" × ⅛"	78 274 100	0.78 2.74 1.00	3.3 11.8 4.2	0.1 0.4 0.2	2.4 8.2 2.9	0 0 0	0.8 2.8 1.0	0 0 0	1.4 5.0 1.8
Lamb, rib chop, medium fat	28 100 85	1.0 3.5 3.0	(A.P. 1.3 oz.) 1 chop raw 1 chop broiled	101 356 356	1.01 3.56 3.56	2.1 7.3 9.9	0.1 0.4 0.4	1.6 5.8 6.8	(0) (0) (0)	0.8 2.6 2.4	0 0 0	1.0 3.6 4.4
Lard	14	0.5	1 tbsp.	126	1.26	0	0	0	0	0	0	0
Lemon juice	14	0.5	1 tbsp.	3	0.03	0.0	0.1	0.0	0	0.2	3.0	0.0
Lentils, dried, split	28 100 29	1.0 3.5 1.0	½ cup 2 tbsp.	96 339 100	0.96 3.39 1.00	3.3 11.8 3.4	0.4 1.4 0.4	5.5 19.5 5.5	1.0 3.7 1.1	3.2 11.2 3.2	0.4 2.1 0.4	1.4 4.8 1.4
Lettuce, headed	28 100 667	1.0 3.5 23.5	(A.P. 1.4 oz.) 5 large leaves 1½ heads, 4¾" diam.	4 15 100	0.04 0.15 1.00	0.1 0.6 3.9	0.2 0.9 5.9	0.3 1.3 8.7	0.7 2.5 16.5	0.4 1.4 9.4	1.3 4.7 31.2	0.4 1.2 8.0
Lettuce, loose leaf and Romaine	28 100	1.0 3.5	3 leaves, 8" long ½ head, 4" diam.	4 15	0.04 0.15	0.1 0.6	0.7 2.5	0.8 2.9	7.0 24.7	0.4 1.4	1.3 4.7	0.8 3.0
Liver, beef, raw	28 100 74	1.0 3.5 2.6	(A.P. 1.0 oz.) 1 piece, 3" × 3" × ⅓"	39 136 100	0.39 1.36 1.00	2.8 9.7 7.2	0.1 0.3 0.2	5.0 17.4 12.9	79.9 281.4 206.9	1.4 5.2 3.8	3.8 13.2 9.8	19.0 66.6 49.2
Liver, beef, fried	100	3.5	1 piece, 3" × 3" × ⅓"	207	2.07	11.6	0.4	20.5	342.9	5.2	13.0	78.8
Liver, calf, raw	114	4.0		160	1.60	10.6	0.3	31.8	163.1	4.8	17.1	70.4
Liver, chicken, raw	114	4.0		160	1.60	12.3	0.8	22.1	233.3	4.6	9.8	55.8
Liver, pork, raw	114	4.0		152	1.52	10.9	0.4	53.4	102.9	9.0	10.7	67.2
Liver, lamb, raw	114	4.0		154	1.54	11.7	0.4	37.4	366.0	8.6	15.8	74.2
Liverwurst	(see Sausage, liver)											
Lobster, boiled or canned	28 100 109	1.0 3.5 3.8	(A.P. 2.8 oz.)* ¾ cup	26 92 100	0.26 0.92 1.00	2.6 9.1 9.9	0.7 2.6 2.8	0.5 2.1 2.4	0.3 1.0 1.1	(0.2) (1.0) (1.0)	- - -	0.4 1.4 1.6
* Whole.												

* Whole.

Table II (Continued). NUTRITIVE VALUES OF FOODS IN SHARES

Food	Weight		Approximate Measure	Calo-ries	Shares						
	Gm.	Oz.			Pro-tein	Cal-cium	Iron	Vita-min A	Thia-mine	Ascorbic Acid	Ribo-flavin
Loganberries, raw	28	1.0	(A.P. 1.0 oz.)	18	0.1	0.4	0.8	0.1	0.2	3.0	(0.4)
	100	3.5	$\frac{2}{3}$ cup	62	0.5	1.4	3.2	0.2	0.6	10.3	(1.4)
	161	5.7	1 $\frac{1}{8}$ cups	100	0.8	2.2	5.0	0.3	1.0	16.7	(2.2)
Macaroni, enriched, uncooked	28	1.0	10 sticks, 9" long	107	1.8	0.2	2.1	(0)	5.0	0	2.2
	100	3.5	$\frac{1}{4}$ cup, 1" pieces	377	6.3	0.9	7.6	(0)	17.6	0	7.4
	27	1.0	$\frac{1}{4}$ cup, 1" pieces	100	1.7	0.2	2.1	(0)	4.8	0	2.0
Macaroni, enriched	172	6.1	1 cup cooked	200	3.3	0.5	3.7	(0)	4.6	(0)	2.8
Macaroni, unenriched, uncooked	28	1.0	10 sticks, 9" long	107	1.8	0.2	1.1	(0)	0.6	0	0.4
	100	3.5	$\frac{1}{4}$ cup, 1" pieces	377	6.3	0.9	3.9	(0)	1.8	0	1.2
	27	1.0	$\frac{1}{4}$ cup, 1" pieces	100	1.7	0.2	1.1	(0)	0.4	0	0.4
Mackerel	(see Fish)										
Mangoes, raw	28	1.0	(A.P. 1.5 oz.)	19	0.1	0.1	0.3	11.6	0.4	5.1	0.4
	100	3.5	$\frac{1}{2}$ medium	66	0.3	0.4	0.5	40.7	1.2	17.5	1.2
	152	5.4		100	0.5	0.6	0.8	61.9	1.8	26.5	1.8
Mayonnaise	14	0.5	1 tbsp.	100	0.1	0.1	0.3	0.2	0.0	0	0.2
Margarine	28	1.0		204	0.1	0.2	0.0	6.0 *	0.0	0	0.2
	100	3.5		720	0.3	0.8	0.0	21.2 *	0.2	0	0.6
	14	0.5	1 tbsp.	100	0.0	0.1	0.0	3.0 *	0.0	0	0.0
* Based on addition of 15,000 I.U. per pound (96.2 shares).											
Milk, buttermilk, cultured *	28	1.0		10	0.5	1.4	0.0	0.0	0.2	0.0	1.0
	100	3.5		36	1.7	4.7	0.3	0.0	0.8	0.4	3.6
	278	9.8	1 $\frac{1}{8}$ cups	100	4.8	13.1	0.8	0.1	2.2	1.3	10.0
* Made from skim milk.											
Milk, chocolate drink, commercial	244	8.6	1 cup	146	4.2	11.8	0.8	0.1	1.6	1.3	8.6
	28	1.0		91	1.1	3.1	0.3	(0.8)	0.2	0.0	2.2
	100	3.5	$\frac{1}{3}$ cup	320	4.0	10.9	0.5	(2.8)	1.0	0.4	7.8
Milk, condensed, sweetened	31	1.1	1 $\frac{1}{2}$ tbsp.	100	1.2	3.4	0.3	(0.9)	0.4	0.0	2.4
	28	1.0		39	1.0	2.8	0.3	0.7	0.4	0.0	2.0
	100	3.5	$\frac{2}{3}$ cup	138	3.4	9.7	0.5	2.6	1.4	0.4	7.2
Milk, evaporated, unsweetened	72	2.5	4 $\frac{1}{2}$ tbsp.	100	2.5	7.0	0.3	1.8	1.0	0.4	5.2
	252	8.9	1 cup	348	8.7	24.5	1.3	6.5	3.6	1.3	18.2
	244	8.6	1 cup	164	4.0	12.6	0.5	(2.5)	2.0	0.9	5.2

Table II (Continued). NUTRITIVE VALUES OF FOODS IN SHARES

Food	Weight		Approximate Measure	Calo- ries	Shares						
	Gm.	Oz.			Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascorbic Acid	Ribo- flavin
Milk, malted, dry	28	1.0		116	2.0	3.3	1.6	1.9	2.0	(0)	2.8
	100	3.5	$\frac{3}{4}$ cup	407	7.2	11.5	5.5	6.5	6.8	(0)	10.0
	25	0.9	3 tbsp.	100	1.8	2.9	1.3	1.6	1.8	(0)	2.6
Milk, skim, dried	100	3.5	$\frac{3}{4}$ cup	362	17.5	52.0	1.6	(0.3)	7.0	3.0	39.2
	28	1.0	$3\frac{1}{3}$ tbsp.	100	4.9	14.6	0.5	(0.1)	2.0	0.9	11.0
Milk, skim, fluid	28	1.0		10	0.5	1.4	0.0	(0.0)	0.2	0.4 *	1.0
	100	3.5	$\frac{3}{4}$ cup	36	1.7	4.9	0.3	(0.0)	1.0	0.9 *	3.6
	278	9.8	$1\frac{1}{8}$ cups	100	4.8	13.6	0.8	(0.1)	2.8	2.6 *	10.0
	246	8.7	1 cup	87	4.2	12.1	0.6	(0.1)	2.4	2.1 *	8.8
* Pasteurized.											
Milk, whole, fluid (cows')	28	1.0		19	0.5	1.4	0.0	0.4	0.2	0.4 *	1.0
	100	3.5	$\frac{3}{4}$ cup	68	1.7	4.7	0.3	1.2	0.8	0.9 *	3.6
	147	5.2	cup	100	2.5	6.9	0.3	1.8	1.2	1.3 *	5.2
	244	8.6	1 cup	166	4.2	11.5	0.5	3.1	1.8	2.1 *	8.8
	976	34.4	1 quart	666	16.8	46.1	1.8	12.2	7.0	8.5 *	35.2
* Pasteurized.											
Molasses, cane, medium	28	1.0		66	(0)	3.3	4.5	(0)	0.4	(0)	1.0
	100	3.5	$4\frac{1}{2}$ tbsp.	232	(0)	11.6	15.8	(0)	1.6	(0)	3.2
	43	1.5	2 tbsp.	100	(0)	5.0	6.8	(0)	0.6	(0)	1.4
Mushrooms, raw	28	1.0	(A.P. 1.1 oz.)	7	0.3	0.1	0.5	0	0.6	0.4	2.4
	100	3.5	10 mushrooms, $1\frac{1}{2}$ " diam.	23	1.2	0.4	2.1	0	2.4	2.1	8.8
Mustard greens, raw	28	1.0	(A.P. 1.4 oz.)	6	0.3	2.5	2.1	18.2	0.6	9.0	1.6
	100	3.5		22	1.1	8.8	7.6	64.1	1.8	32.0	5.8
	455	16.0		100	5.2	40.0	34.7	291.7	8.2	145.7	26.4
Mustard greens	140	4.9	1 cup cooked	31	1.6	12.3	10.8	64.4	1.6	26.9	5.0
Nectarines, raw	28	1.0	(A.P. 1.1 oz.)	17	0.0	0.0	0.3	2.7 *		0.9	
	100	3.5		60	0.2	0.2	1.3	9.6 *		3.4	
	167	5.9	3 nectarines, $1\frac{3}{4}$ " diam.	100	0.4	0.3	2.1	16.1 *		5.6	
* For yellow; only a trace in white.											
Noodles, egg, enriched, uncooked	28	1.0		108	1.8	0.2	2.1	0.4	5.0	0	2.2
	100	3.5	$1\frac{3}{4}$ cups, $1\frac{1}{2}$ " strips, $\frac{3}{4}$ " wide	381	6.2	0.9	7.6	1.3	17.6	0	7.4
	26	0.9	$\frac{1}{2}$ cup, scant	100	1.6	0.2	2.1	0.4	4.6	0	2.0

Table II (Continued). NUTRITIVE VALUES OF FOODS IN SHARES

Food	Weight		Approximate Measure	Calo- ries	Shares						
	Gm.	Oz.			Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascorbic Acid	Ribo- flavin
Noodles, egg, enriched	126	4.4	1 cup cooked	129	1.4	0.2	1.6	0.2	3.6	(0)	1.6
Noodles, egg, unenriched,	28	1.0	1½ cups, 1½" strips, ¾" wide	108	1.8	0.2	1.3	0.4	1.2	0	0.6
uncooked	100	3.5		381	6.2	0.9	5.0	1.3	4.0	0	2.2
	26	0.9	½ cup, scant	100	1.6	0.2	1.3	0.4	1.0	0	0.6
Oatmeal,	28	1.0	1½ cups ¾ cup	111	2.0	0.6	3.7	(0)	3.4	0	0.8
rolled oats,	100	3.5		392	7.0	2.1	13.2	(0)	12.2	0	2.8
uncooked	26	0.9		100	1.8	0.6	3.4	(0)	3.2	0	0.8
Oatmeal	236	8.3	1 cup cooked	148	2.7	0.8	4.5	(0)	4.4	(0)	1.0
Oats, ready-to- eat cereal	28	1.0	4 cups 1 cup	113	2.0	1.8	3.2	(0)	4.4	(0)	1.0
	100	3.5		398	7.1	6.4	10.8	(0)	15.8	(0)	3.8
	25	0.9		100	1.8	1.6	2.6	(0)	4.0	(0)	1.0
Oils, salad or cooking	100	3.5	1 tbsp.	884	0	0	0	0*	0	0	0
	11	0.4		100	0	0	0	0*	0	0	0
* Red palm oil, 83.8 shares vitamin A per 100 gm.											
Okra, raw	28	1.0	(A.P. 1.1 oz.)	9	0.2	0.9	0.5	1.3	0.8	3.8	0.4
	100	3.5	9 pods, 3" long	32	0.9	3.3	1.8	4.7	2.6	12.8	1.4
	313	11.0		100	2.8	10.3	5.8	14.8	8.2	40.2	4.4
Olives, green, pickled	28	1.0	(A.P. 1.2 oz.)	37	0.2	1.0	1.3	0.5	Trace	-	-
	100	3.5	12 olives,* 1½" × ¾"	132	0.7	3.5	4.2	1.9	Trace	-	-
* Weight with pits, 114 gm.											
Olives, ripe, pickled	28	1.0	(A.P. 1.2 oz.)	54	0.2	1.0	1.3	0.1	Trace	-	Trace
	100	3.5	12 olives,* 1½" × ¾"	191	0.9	3.5	4.2	0.4	Trace	-	Trace
* Weight with pits, 114 gm.											
Onions, raw	28	1.0	(A.P. 1.1 oz.)	13	0.2	0.4	0.3	0.1	0.2	1.3	0.2
	100	3.5	½ cup, sliced	45	0.7	1.3	1.3	0.3	0.6	3.8	0.8
	222	7.8	2 onions, 2½" diam.	100	1.5	2.8	2.9	0.7	1.4	8.5	1.8
Onions	210	7.4	1 cup cooked	79	1.0	2.7	2.6	0.7	0.8	5.6	1.2
Orange juice	28	1.0	½ cup, scant ¾ cup 1 cup	12	0.1	0.2*	0.3	(0.3)*	0.4	6.4	0.2
	100	3.5		44	0.4	0.8*	0.8	(1.2)*	1.6	22.6	1.0
	227	8.0		100	0.9	1.7*	1.8	(2.8)*	3.6	51.3	2.2
	246	8.7		108	1.0	1.9*	1.8	(3.0)*	4.0	55.5	2.4
* Fresh; canned, per 100 gm., calcium 0.4, vitamin A (0.6).											

Table II (Continued). NUTRITIVE VALUES OF FOODS IN SHARES

Food	Weight		Calo- ries	Shares							
	Gm.	Oz.		Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascorbic Acid	Ribo- flavin	
Orange juice, frozen concentrate	257	9.1	100	0.9	0.9	1.8	1.4	3.2	40.6	0.8	
Oranges	28 100 222 155	1.0 3.5 7.8 5.5	13 45 100 70	(A.P. 1.4 oz.) 2 small, 2½" diam. 1 medium, 3" diam.	0.1 0.4 1.0 0.7	0.4 1.3 2.9 2.0	0.3 1.1 2.4 1.6	0.4 1.4 3.2 2.2	6.4 22.6 50.4 35.0	0.2 1.0 2.2 1.6	
Oysters, solids, raw or canned	28 100 119	1.0 3.5 4.2	24 84 100	¾ cup 5 medium or ½ cup	1.4 4.8 5.8	1.1 3.8 4.5	4.5 15.8 18.7	0.5 1.6 1.9	0.4 1.3 1.7	2.0 7.0 8.4	
Pablum	28 100	1.0 3.5	105 367	12 tbsp. 2½ cups	2.1 7.4	8.8 31.2	22.4 78.9	6.0 21.0		2.0 7.0	
Papayas, raw	28 100 256	1.0 3.5 9.0	11 39 100	(A.P. 1.5 oz.) ¾ cup 1¾ cups, ¾" cubes	0.1 0.3 0.7	0.2 0.8 2.0	0.3 0.8 2.1	3.2 11.2 28.8	9.0 32.0 82.0	0.2 0.8 2.0	
Parsnips, raw	28 100 128	1.0 3.5 4.5	22 78 100	(A.P. 1.3 oz.) ½ cup, cubes 1 parsnip, 7" long	0.2 0.7 0.9	0.6 2.3 2.9	0.5 1.8 2.4	0 0 0	2.6 9.0 11.5	0.4 1.6 2.0	
Parsnips	155	5.5	94	1 cup cooked	0.8	3.5	2.9	0	8.1	3.2	
Peaches, canned in syrup	28 100 147	1.0 3.5 5.2	19 68 100	¾ cup 3 small halves, 3 tbsp. juice	0.0 0.2 0.3	0.0 0.2 0.3	0.3 1.1 1.6	0.8* 2.9* 4.2*	0.4 1.7 2.6	0.2 0.4 0.6	
* For yellow; none in white.											
Peaches, raw	28 100 217	1.0 3.5 7.7	13 46 100	(A.P. 1.3 oz.) 1 medium, 2½" × 2" 1½ cups, sliced	0.0 0.2 0.5	0.1 0.3 0.7	0.5 1.6 3.4	1.6* 5.6* 12.2*	0.9 3.4 7.3	0.2 1.0 2.2	
* For yellow; white, 0.3 per 100 gm.											
Peanut butter	28 100 17	1.0 3.5 0.6	164 576 100	6 tbsp. 1 tbsp.	3.6 12.9 2.2	0.8 3.0 0.5	1.3 5.0 0.8	0 0 0	(0) (0) (0)	1.0 3.2 0.6	
Peanuts, roasted	28 100 18	1.0 3.5 0.6	159 559 100	(A.P. 1.4 oz.) ¾ cup, shelled 20 kernels	3.7 13.3 2.4	0.8 3.0 0.5	1.3 5.0 0.8	0 0 0	(0) (0) (0)	1.0 3.2 0.6	

Table II (Continued). NUTRITIVE VALUES OF FOODS IN SHARES

Food	Weight		Approximate Measure	Calo- ries	Shares						
	Gm.	Oz.			Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascorbic Acid	Ribo- flavin
Pears, canned in syrup	28	1.0		19	0.0	0.1	0.3	Trace	0.0	0.4	0.2
	100	3.5	$\frac{3}{4}$ cup	68	0.1	0.3	0.5	Trace	0.2	0.9	0.4
	147	5.2	3 halves, 3 tbsp. juice	100	0.1	0.5	0.8	Trace	0.2	1.3	0.6
Pears, raw	28	1.0	(A.P. 1.2 oz.)	18	0.1	0.2	0.3	0.0	0.4	0.4	0.6
	100	3.5		63	0.3	0.5	0.8	0.1	1.2	1.7	1.8
	159	5.6	1 pear, 3" long	100	0.5	0.8	1.3	0.2	2.0	2.6	2.8
Peas, canned, drained	28	1.0		26	0.6	0.4	1.6	1.2	0.6	1.3	0.4
	100	3.5	$\frac{3}{4}$ cup	91	2.2	1.3	5.5	4.3	2.4	3.8	1.2
	110	3.9	$\frac{3}{4}$ cup	100	2.5	1.4	6.1	4.7	2.6	4.3	1.4
Peas, dried, split	28	1.0		98	3.4	0.4	3.7	0.7	4.4	0	1.6
	100	3.5	$\frac{1}{2}$ cup	344	12.1	1.3	13.4	2.4	15.4	0	5.6
	29	1.0	2 tbsp.	100	3.5	0.4	3.9	0.7	4.4	0	1.6
Peas, frozen	149	5.3	1 cup uncooked	112	4.2	1.0	5.8	6.4	9.8	11.5	3.2
	156	5.5	1 cup cooked	150	5.6	1.4	7.6	8.6	13.2	15.4	4.2
Peas, green, raw	28	1.0	(A.P. 1.6 oz.)	28	0.9	0.2	1.3	1.7	2.2	4.0	1.0
	100	3.5		98	3.3	0.9	5.0	6.1	7.8	10.3	3.6
	102	3.6	$\frac{3}{4}$ cup	100	3.3	0.9	5.0	6.2	8.0	10.3	3.6
Peas, green	160	5.6	1 cup cooked	111	3.8	1.4	7.9	7.4	8.0	10.3	4.4
Pecans	28	1.0	(A.P. 1.5 oz.)	198	1.3	0.8	1.8	0.1	4.0	0.4	0.6
	100	3.5		696	4.6	3.0	6.3	0.3	14.4	0.9	2.2
	14	0.5	12 meats	100	0.6	0.4	0.8	0.0	2.0	0.0	0.4
Peppers, green, raw	28	1.0	(A.P. 1.2 oz.)	7	0.1	0.1	0.3	5.1	0.2	14.5	0.4
	100	3.5		25	0.6	0.4	1.1	17.9	1.0	51.3	1.4
	400	14.1	5 peppers, 3 $\frac{1}{2}$ " long	100	2.4	1.8	4.2	71.8	4.0	205.1	5.6
Pickles, cucumber, sour and dill	100	3.5		11	0.3	1.0	3.2	2.0	0.2	2.6	1.2
	909	32.1	7 pickles, 3 $\frac{3}{4}$ " long	100	3.2	9.1	28.7	18.1	1.8	23.5	11.0
Pineapple, canned in syrup	28	1.0		22	0.0	0.3	0.5	0.1	0.4	1.3	0.2
	100	3.5	$\frac{3}{4}$ cup, crushed	78	0.2	1.2	1.6	0.5	1.4	3.8	0.4
	128	4.5	1 large slice, 2 tbsp. juice	100	0.2	1.5	2.1	0.7	1.8	5.1	0.6
Pineapple, raw	28	1.0	(A.P. 1.5 oz.)	15	0.0	0.2	0.3	0.2	0.4	3.0	0.2
	100	3.5	$\frac{3}{4}$ cup, $\frac{1}{2}$ " pieces	52	0.2	0.6	0.8	0.8	1.6	10.3	1.0
	192	6.8	2 slices, $\frac{7}{8}$ " thick	100	0.4	1.2	1.6	1.6	3.0	19.7	2.0

Table II (Continued). NUTRITIVE VALUES OF FOODS IN SHARES

Food	Weight		Approximate Measure	Calo- ries	Shares						
	Gm.	Oz.			Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascorbic Acid	Ribo- flavin
Pineapple juice, canned	28 100 204	1.0 3.5 7.2	$\frac{3}{4}$ cup $\frac{1}{2}$ cup	14 49 100	0.0 0.1 0.3	0.2 0.6 1.2	0.3 1.3 2.6	0.1 0.5 1.0	0.2 1.0 2.0	1.3 3.8 7.7	0.2 0.4 0.8
Plantains (baking bananas)	28 100 84	1.0 3.5 3.0	(A.P. 1.2 oz.) 1 medium	34 119 100	0.1 0.5 0.4	0.1 0.3 0.2	0.5 1.8 1.6	* * *	0.4 1.2 1.0	1.7 6.0 5.1	0.2 0.8 0.6
* Vitamin A, 0.1 share per 100 gm. in white to 7.7 shares in yellow.											
Plums, canned in syrup	28 100 132	1.0 3.5 4.7		22 76	0.0 0.2	0.1 0.3	0.8 2.9	0.4 1.5	0.2 0.6	0.0 0.4	0.2 0.6
			4 plums, $1\frac{3}{4}$ " diam., 2 tbsp. juice	100	0.2	0.4	3.9	1.9	0.8	0.4	0.8
Plums, raw	28 100 200	1.0 3.5 7.1	(A.P. 1.1 oz.)	14 50 100	0.1 0.3 0.7	0.2 0.7 1.4	0.3 1.3 2.6	0.6 2.2 4.5	0.6 2.4 4.8	0.9 2.6 5.1	0.2 0.8 1.6
Pork, loin chops, medium fat, raw	28 100 34	1.0 3.5 1.2	(A.P. 1.2 oz.) 1 chop	84 296 100	2.3 8.1 2.8	0.1 0.4 0.1	1.8 6.6 2.4	(0) (0) (0)	4.6 16.0 5.4	0 0 0	1.0 3.8 1.2
Pork, loin chops	115	4.1	1 chop cooked (with bone)	293	9.9	0.4	6.8	(0)	14.4	0	4.2
Pork, loin, roasted, lean only	28 100 30	1.0 3.5 1.1		95 333 100	3.2 11.3 3.4	0.1 0.4 0.1	2.4 7.9 2.4	(0) (0) (0)	4.8 16.6 5.0	0 0 0	1.4 4.8 1.4
Pork, salt, fat	100 13	3.5 0.5		783 100	1.9 0.2	0.1 0.0	1.6 0.3	(0) (0)	(3.6) (0.4)	0 0	(0.8) (0.2)
Potato, baked	132	4.7	1 medium, in skin	100	1.2	0.5	2.1	0.1	2.2	7.7	1.0
Potato, boiled	128	4.5	1 medium, unpeeled	100	1.2	0.6	2.4	0.2	2.4	8.1	1.0
Potato chips	17	0.6	8 to 10 pieces, 2" to 3" diam.	92	0.5	(0.2)	(0.8)	(0.1)	(0.6)	0.9	(0.4)
Potato, French fried	40	1.4	8 pieces, $2'' \times \frac{1}{2}'' \times \frac{1}{2}''$	157	1.1	0.5	2.1	0.1	1.4	4.8	0.8
Potato, white, raw	28 100 120	1.0 3.5 4.2	(A.P. 1.2 oz.) 1 medium	24 83 100	0.3 1.0 1.2	0.1 0.4 0.5	0.5 1.8 2.1	0.1 0.2 0.3	0.6 2.2 2.6	2.1 7.3 8.5	0.2 0.8 1.0

Table II (Continued). NUTRITIVE VALUES OF FOODS IN SHARES

Food	Weight		Approximate Measure	Calo- ries	Shares						
	Gm.	Oz.			Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascorbic Acid	Ribo- flavin
Prune juice, canned	28	1.0	¾ cup	20	0.0	0.1	1.3	—	0.2	0.4	(0.4)
	100	3.5		71	0.2	0.4	4.2	—	1.0	1.3	(1.6)
	141	5.0		100	0.3	0.6	6.1	—	1.4	1.7	(2.2)
Prunes, dried (not sulfured)	28	1.0	(A.P. 1.2 oz.)	76	0.3	0.6	2.9	3.4	0.6	0.4	1.0
	100	3.5		268	1.1	2.2	10.3	12.1	2.0	1.3	3.2
	37	1.3		100	0.4	0.8	3.7	4.5	0.8	0.4	1.2
Radishes, raw	28	1.0	(A.P. 1.5 oz.)	6	0.1	0.4	0.8	0.1	0.4	2.1	0.2
	100	3.5		20	0.6	1.5	2.6	0.2	1.4	7.7	0.6
Raisins, dried (unsulfured)	28	1.0	1 cup, seeded 2½ tbsp., seedless	76	0.3	0.7	2.4	0.1	0.8	0	0.4
	100	3.5		268	1.1	2.4	8.7	0.3	3.0	0	1.6
	37	1.3		100	0.4	0.9	3.2	0.1	1.2	0	0.6
Raspberries, red, raw	28	1.0	(A.P. 1.0 oz.)	16	0.1	0.4	0.8	0.2	0.2	3.0	0.4
	100	3.5		57	0.6	1.6	2.4	0.8	0.4	10.3	1.4
	175	6.2		100	1.0	2.8	4.2	1.5	0.8	17.9	2.4
Rhubarb, raw	28	1.0	(A.P. 1.3 oz.)	5	0.0	0.5 *	0.3	0.1	0.2	2.1	—
	100	3.5		16	0.2	1.8 *	1.3	0.4	0.4	7.3	—
	625	22.0		100	1.5	11.0 *	8.2	2.6	2.6	45.3	—
* Availability doubtful.											
Rice, brown, uncooked	100	3.5	½ cup 2 tbsp.	360	3.7	1.6	5.3	0.3	6.4	0	1.0
	28	1.0		100	1.0	0.4	1.6	0.1	1.8	0	0.2
Rice, converted, uncooked	100	3.5	½ cup 2 tbsp.	362	3.7	1.0	2.1	(0)	4.0	0	0.6
	28	1.0		100	1.0	0.3	0.5	(0)	1.2	0	0.2
Rice, puffed, restored	28	1.0	2 cups	111	0.8	0.2	1.3	(0)	2.6	(0)	0.4
	100	3.5		392	2.9	0.8	4.7	(0)	9.2	(0)	1.6
	26	0.9		100	0.7	0.2	1.3	(0)	2.4	(0)	0.4
Rice, white, uncooked	100	3.5	½ cup 2 tbsp.	362	3.7	0.4	2.1	(0)	1.4	0	0.6
	28	1.0		100	1.0	0.1	0.5	(0)	0.4	0	0.2
Rice, white	168	5.9	1 cup cooked	201	2.1	0.5	1.3	(0)	0.4	(0)	0.2
Roe, shad	28	1.0	½ medium	40	3.6	0.3	0.8	3.6	5.6	0.4	0.6
	100	3.5		140	12.9	0.9	3.2	12.8	20.0	2.1	2.0
	71	2.5		100	9.2	0.6	2.4	9.1	14.2	1.7	1.4
Rolled oats				(see Oatmeal)							

Table II (Continued). NUTRITIVE VALUES OF FOODS IN SHARES

Food	Weight		Approximate Measure	Calo- ries	Shares							
	Gm.	Oz.			Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascorbic Acid	Ribo- flavin	
Rolls, commercial, enriched	38	1.3	1 roll, medium	118	1.18	1.7	0.8	1.8	0	1.8	(0)	1.2
Romaine	(see Lettuce)											
Rutabagas	28	1.0	(A.P. 1.2 oz.)	11	0.11	0.1	0.6	0.3	0.6	0.4	4.3	0.4
	100	3.5		38	0.38	0.5	2.2	1.3	2.1	1.2	15.4	1.2
	263	9.3	1½ cups, ½" cubes	100	1.00	1.4	5.8	3.4	5.6	3.2	40.6	3.2
Salad oil	(see Oils)											
Salmon	(see Fish)											
Sardines	(see Fish)											
Sauerkraut, canned, drained	28	1.0		6	0.06	0.2	0.4	(0.3)	0.1	0.2	2.1	0.4
	100	3.5	¾ cup	22	0.22	0.7	1.4	(1.3)	0.3	0.6	6.8	1.2
	455	16.0	3 cups	100	1.00	3.2	6.6	(6.1)	1.2	2.8	31.2	5.4
Sausage, bologna (added cereal)	28	1.0		63	0.63	2.1	0.1	1.6	(0)	1.0	0	1.0
	100	3.5	1 piece, 2½" diam., ½" thick	221	2.21	7.3	0.4	5.8	(0)	3.6	0	3.8
	45	1.6		100	1.00	3.3	0.2	2.6	(0)	1.6	0	1.8
Sausage, frank- furter	28	1.0		73	0.73	2.0	0.1	1.1	(0)	1.0	0	1.0
	100	3.5		257	2.57	7.0	0.3	3.9	(0)	3.6	0	3.8
(added cereal)	39	1.4	1 sausage	100	1.00	2.7	0.1	1.6	(0)	1.4	0	1.4
Sausage, liver (liverwurst)	28	1.0		75	0.75	2.3	0.1	3.9	10.5	1.0	(0)	6.4
	100	3.5		263	2.63	8.2	0.4	14.2	36.9	3.4	(0)	22.4
	38	1.3	1 slice, 3½" diam., ½" thick	100	1.00	3.1	0.1	5.5	14.0	1.2	(0)	8.6
Sausage, pork	28	1.0		128	1.28	1.5	0.1	1.3	(0)	2.4	0	1.0
	100	3.5		450	4.50	5.3	0.2	4.2	(0)	8.6	0	3.4
	22	0.8	¾ sausage, 4½" long	100	1.00	1.2	0.0	1.1	(0)	1.8	0	0.8
Scallops	28	1.0		22	0.22	2.1	0.3	1.3	0	(0.2)	-	0.6
	100	3.5		78	0.78	7.3	1.0	4.7	0	(0.8)	-	2.0
	128	4.5	¾ cup	100	1.00	9.7	1.3	6.1	0	(1.0)	-	2.6
Shad	(see Fish)											
Shrimp, canned, solids	28	1.0		36	0.36	3.7	1.3	1.6	0.1	0.0	(0)	0.2
	100	3.5	20 shrimps	127	1.27	13.2	4.6	5.3	0.4	0.2	(0)	0.6
	79	2.8	¾ cup	100	1.00	10.4	3.6	4.2	0.3	0.2	(0)	0.4

Table II (Continued). NUTRITIVE VALUES OF FOODS IN SHARES

Food	Weight		Approximate Measure	Calo- ries	Shares							
	Gm.	Oz.			Calo- ries	Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascorbic Acid	Ribo- flavin
Soybean curd	28	1.0	1 portion, 2½" × 2½" × 1"	20	0.20	1.0	1.1	1.1	—	0.4	0	0.2
	100	3.5		71	0.71	3.4	4.0	3.9	—	1.2	0	1.0
	141	5.0		100	1.00	4.9	5.6	5.5	—	1.6	0	1.4
Soybean flour, medium fat	28	1.0	¾ cup 4½ tbsp.	75	0.75	6.0	2.8	2.1	0.2	4.6	(0)	2.0
	100	3.5		263	2.63	20.9	9.8	7.1	0.7	16.4	(0)	6.8
	38	1.3		100	1.00	8.0	3.7	2.6	0.3	6.2	(0)	2.6
Soybean sprouts, raw	28	1.0	1 cup	17	0.17	0.9	0.6	0.8	0.3	1.4	1.7	1.2
	100	3.5		59	0.59	3.1	1.9	2.6	1.2	4.6	5.6	4.0
	169	6.0		100	1.00	5.2	3.2	4.5	1.9	7.8	9.4	6.8
Soybeans, dried	28	1.0	¾ cup 2 tbsp.	93	0.93	4.9	2.6	6.1	0.2	6.0	Trace	1.8
	100	3.5		329	3.29	17.2	9.1	20.1	0.7	21.4	Trace	6.2
	30	1.1		100	1.00	5.2	2.7	6.3	0.2	6.4	Trace	1.8
Spaghetti, enriched, uncooked	28	1.0	1 cup, 2" pieces	107	1.07	1.8	0.2	2.1	(0)	5.0	(0)	2.2
	100	3.5		377	3.77	6.3	0.9	7.6	(0)	17.6	(0)	7.4
	26	0.9		100	1.00	1.6	0.2	2.1	(0)	4.6	(0)	2.0
Spaghetti, enriched	146	5.1	1 cup cooked	218	2.18	3.6	0.5	4.2	(0)	5.0	(0)	3.0
Spinach	28	1.0	(A.P. 1.2 oz.)	6	0.06	0.3	0.9 *	2.4	(18.2)	0.6	4.7	1.4
	100	3.5		20	0.20	1.1	3.2 *	7.9	(64.1)	2.2	16.2	5.2
	500	17.6		100	1.00	5.7	16.2 *	39.5	(320.5)	11.0	81.2	26.0
* May not be available because of oxalic acid present.												
Spinach	180	6.3	1 cup cooked	46	0.46	2.8	8.9 *	9.5	135.9	2.8	23.1	7.2
* May not be available because of oxalic acid present.												
Squash, summer, raw	28	1.0	(A.P. 1.03 oz.)	5	0.05	0.1	0.2	0.3	0.5	0.2	1.7	0.4
	100	3.5		16	0.16	0.3	0.6	1.1	1.9	0.8	6.4	1.4
	625	22.0		100	1.00	1.9	3.8	6.6	12.0	5.0	40.2	8.8
Squash, summer	210	7.4	1 cup cooked	34	0.34	0.6	1.3	2.1	3.5	1.6	9.8	3.0
Squash, winter (Hubbard), raw	28	1.0	(A.P. 1.3 oz.)	11	0.11	0.2	0.2	0.5	6.4	0.2	0.4	0.4
	100	3.5		38	0.38	0.7	0.8	1.6	22.4	1.0	2.1	1.6
	263	9.3		100	1.00	1.9	2.0	4.2	59.0	2.6	5.6	4.2
Squash, winter	229	8.1	1 cup cooked	86	0.86	1.7	1.7	3.7	72.4	1.8	4.7	4.6
Starch, pure (corn, arrowroot, etc.)	100	3.5	¾ cup	362	3.62	0.2	(0)	(0)	(0)	(0)	(0)	(0)
	28	1.0	3 tbsp.	100	1.00	0.0	(0)	(0)	(0)	(0)	(0)	(0)

Table II (Continued). NUTRITIVE VALUES OF FOODS IN SHARES

Food	Weight		Approximate Measure	Calo- ries	Shares						
	Gm.	Oz.			Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascorbic Acid	Ribo- flavin
Strawberries, raw	28	1.0	(A.P. 1.04 oz.)	11	0.1	0.3	0.5	0.1	0.2	5.6	0.2
	100	3.5	$\frac{1}{2}$ cup	37	0.4	1.1	2.1	0.5	0.6	20.1	1.0
	270	9.5	1 $\frac{3}{4}$ cups	100	1.1	3.0	5.8	1.3	1.6	54.3	2.8
Sugar, brown	100	3.5	$\frac{1}{2}$ cup	370	(0)	3.0 *	6.8	(0)	(0)	(0)	(0)
	27	1.0	3 tbsp.	100	(0)	0.8 *	1.8	(0)	(0)	(0)	(0)
* For dark brown; lower values for light.											
Sugar, granulated	100	3.5	$\frac{1}{2}$ cup	385	(0)	0	0	0	0	0	0
	26	0.9	2 tbsp.	100	(0)	0	0	0	0	0	0
Sugar, maple	100	3.5	1 piece, 1 $\frac{3}{4}$ " \times 1 $\frac{1}{4}$ " \times $\frac{1}{2}$ "	348	0	-	-	0	0	0	0
	29	1.0		100	0	-	-	0	0	0	0
Sweetbreads, beef, medium fat, raw	28	1.0	$\frac{3}{4}$ cup	98	1.7	0.2	1.3	14.0 *	0.8	2.1	3.2
	100	3.5		344	5.8	0.6	4.2				
	29	1.0		100	1.7	0.2	1.3				
Sweet potatoes	28	1.0	(A.P. 1.1 oz.)	35	0.2	0.4	0.5	49.4 *	0.6	8.1	1.6
	100	3.5	123	0.9	1.2	1.8					
	81	2.9	100	0.7	1.0	1.6					
* For yellow varieties.											
Swordfish (see Fish)											
Syrup, table blends	100	3.5	5 tbsp.	286	(0)	1.8	10.8	0	0	(0)	0.2
	35	1.2		100	(0)	0.6	3.7	0	0	(0)	0.0
Syrup, maple	100	3.5	5 tbsp.	276	0	6.5	7.9	0	0	0	0
	36	1.3		100	0	2.4	2.9	0	0	0	0
Tangerines	28	1.0	(A.P. 1.3 oz.)	12	0.1	(0.4)	0.3	(0.8)	0.4	3.8	0.2
	100	3.5	3 medium, 2 $\frac{1}{2}$ " diam.	44	0.4	(1.3)	1.3	(2.7)	1.4	13.2	0.6
	227	8.0		100	0.9	(3.0)	2.9	(6.1)	3.2	29.9	1.4
Tapioca (cassava, manioc, yuca)	100	3.5	$\frac{1}{2}$ cup uncooked	360	0.3	0.5	(2.6)	(0)	0	0	(0)
	28	1.0	2 tbsp. uncooked	100	0.1	0.1	(0.8)	(0)	0	0	(0)
Taro (see Yautia)											
Tomato juice, canned	28	1.0	2 cups	6	0.1	0.1	(0.3)	1.9	0.2	2.1	0.2
	100	3.5		21	0.5	0.3	(1.1)	6.7	1.0	6.8	0.6
	476	16.8		100	2.4	1.3	(5.0)	32.0	4.8	32.5	2.8

Table II (Continued). NUTRITIVE VALUES OF FOODS IN SHARES

Food	Weight		Approximate Measure	Calo- ries	Shares						
	Gm.	Oz.			Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascorbic Acid	Ribo- flavin
Tomatoes, canned	28	1.0		5	0.1	0.1	0.3	1.9	0.4	2.1	0.2
	100	3.5		19	0.5	0.2	1.3	6.7	1.2	6.8	0.6
	526	18.6	2½ cups	100	2.6	1.3	6.8	35.4	6.4	35.9	3.2
Tomatoes, raw	28	1.0	(A.P. 1.1 oz.)	6	0.1	0.1	0.5	2.0	0.4	3.0	0.2
	100	3.5	1 small	20	0.5	0.4	1.6	7.1	1.2	9.8	0.8
	500	17.6	3 tomatoes, 2½" diam.	100	2.5	2.2	7.9	35.3	6.0	49.1	4.0
(see Fish)											
Turkey, medium fat, raw	28	1.0	(A.P. 1.3 oz.)	76	2.8	0.3	2.9	Trace	0.6	(0)	0.8
	100	3.5		268	9.9	0.9	10.0	Trace	1.8	(0)	2.8
	37	1.3	1 slice, 3" × 2½" × ¼"	100	3.6	0.4	3.7	Trace	0.6	(0)	1.0
Turnip greens, raw	28	1.0	(A.P. 1.2 oz.)	9	0.4	3.0	1.8	(18.2)	0.8	16.7	2.6
	100	3.5		30	1.4	10.4	6.3	(64.1)	2.8	58.1	9.2
	333	11.7		100	4.8	34.6	21.1	(213.5)	9.4	193.5	30.6
Turnip greens	145	5.1	1 cup cooked	43	2.1	15.0	9.2	98.5	1.8	37.2	11.8
Turnips, white, raw	28	1.0	(A.P. 1.1 oz.)	9	0.1	0.4	0.3	0.0	0.2	3.4	0.4
	100	3.5		32	0.5	1.6	1.3	0.1	1.0	12.0	1.4
	313	11.0	4 turnips, 2" diam.	100	1.7	5.0	4.2	0.3	3.2	37.6	4.4
Turnips, white	155	5.5	1 cup cooked	42	0.6	2.5	2.1	Trace	1.2	12.0	1.8
(see Rutabaga)											
Veal, leg, lean, raw	28	1.0	(A.P. 1.2 oz.)	44	2.8	0.1	2.4	(0)	0.8	0	1.4
	100	3.5		156	9.7	0.4	7.9	(0)	2.8	0	5.2
	64	2.3	1 slice, 2" × 2¾" × ¼"	100	6.2	0.3	5.0	(0)	1.8	0	3.4
Veal cutlet, raw, medium fat	28	1.0		47	2.7	0.1	2.1	(0)	0.8	0	1.4
	100	3.5		164	9.6	0.4	7.6	(0)	2.8	0	5.2
	61	2.2		100	5.9	0.3	4.7	(0)	1.8	0	3.2
Walnuts, English	28	1.0	(A.P. 1.6 oz.)	186	2.1	1.0	1.6	0.1	2.8	0.4	0.8
	100	3.5	1 cup, halves	654	7.4	3.3	5.5	0.2	9.6	1.3	2.6
	15	0.5	8 to 16 meats	100	1.1	0.5	0.8	0.0	1.4	0.0	0.4
Watermelon	28	1.0	(A.P. 1.5 oz.)	8	0.0	0.1	0.3	0.6	0.2	0.9	0.2
	100	3.5		28	0.2	0.3	0.5	2.1	0.8	2.6	0.8
	357	12.6	1 slice, ¾" thick, 6" diam.	100	0.9	1.0	1.8	7.3	2.8	9.0	2.8

Table II (Continued). NUTRITIVE VALUES OF FOODS IN SHARES

Food	Weight		Approximate Measure	Calo- ries	Shares						
	Gm.	Oz.			Pro- tein	Cal- cium	Iron	Vita- min A	Thia- mine	Ascorbic Acid	Ribo- flavin
Wheat flakes (Pep, Wheaties, etc.), enriched	100 28	3.5 1.0	½ cup	355 100	5.3 1.5	1.8 0.5	11.1 3.2	(0) (0)	11.2 3.2	0 0	3.6 1.0
Wheat germ	100 28	3.5 1.0	1½ cups	361 100	12.4 3.5	3.4 1.0	21.3 6.1	(0) (0)	41.0 11.4	(0) (0)	16.0 4.4
Wheat meal cereal,	28 100	1.0 3.5		98 344	1.8 6.3	0.5 1.8	2.9 10.0	(0) (0)	3.2 11.0	0 0	0.8 3.0
whole grain (Wheatena, etc.)	29 243	1.0 5.0	¾ cup uncooked 1 cup cooked	100 175	1.8 3.3	0.5 0.9	2.9 4.5	(0) (0)	3.2 5.0	0 0	0.8 1.6
Wheat, puffed, restored	100 28	3.5 1.0	2½ cups	355 100	5.3 1.5	1.8 0.5	11.1 3.2	0 0	11.2 3.2	0 0	3.6 1.0
Wheat, shredded	100 28	3.5 1.0	1 large biscuit	360 100	5.0 1.4	1.9 0.5	9.2 2.6	0 0	4.4 1.2	0 0	2.4 0.6
Yams, white, raw	28 100 99	1.0 3.5 3.5	(A.P. 1.1 oz.)	29 101 100	0.3 1.0 1.0	0.2 0.8 0.8	0.5 1.6 1.6	Trace Trace Trace	0.6 2.0 2.0	1.3 3.8 3.8	0.2 0.8 0.8
Yautia, white (taro, dasheen, tania, etc.)	28 100 111	1.0 3.5 3.9	(A.P. 1.2 oz.) ¾ yautia, 4" long	26 90 100	0.3 1.0 1.1	0.3 1.0 1.1	0.8 2.6 2.9	0.0 0.1 0.1	0.8 2.6 2.8	0.4 1.7 1.7	0.2 0.8 0.8
Yeast, dried (brewer's)	28 100 40	1.0 3.5 1.4	5 tbsp.	71 249 100	(5.2) (18.2) (7.3)	1.2 4.2 1.7	13.7 47.9 19.2	(0) (0) (0)	55.0 193.8 77.6	(0) (0) (0)	31.0 109.0 43.6

NOTE ON TABLE III

At the meeting of the National Nutrition Conference called by President Roosevelt and held in Washington in May, 1941, the Food and Nutrition Board of the National Research Council presented the Recommended Dietary Allowances given in this table. These figures, to quote the Board, were obtained as follows: ". . . the literature on the subject of each of the dietary essentials was critically appraised, and in addition judgments as to the various requirements were solicited from a considerable number of nutrition authorities in addition to members of the Board, especially those whose research bore particularly on the problem. On the basis of this evidence tentative allowances were formulated.

These were resubmitted to contributors for criticism and reformulated in the light of the comments made. The values thus revised were presented before a section meeting of the American Institute of Nutrition in 1941 and members invited to submit further evidence for any changes that seemed indicated. After final discussion and some minor revisions they were adopted by the Board in May, 1941. . . . The term 'Recommended Allowances' rather than 'Standards' was adopted by the Board to avoid any implication of finality."

Since 1941 these Recommended Daily Dietary Allowances have been reviewed and revised twice—in 1948 and again in 1953.

Table III(a). FOOD AND NUTRITION BOARD, NATIONAL RESEARCH COUNCIL RECOMMENDED
DAILY DIETARY ALLOWANCES^a, REVISED 1953

Designed for the Maintenance of Good Nutrition of Healthy Persons in the U.S.A.
(Allowances are considered to apply to persons normally vigorous and living in the temperate climate)

	Age, Years	Weight Kg. (Lb.)	Height Cm. (In.)	Calories	Protein Gm.	Cal- cium Gm.	Iron Mg.	Vita- min A I.U.	Thia- mine Mg.	Ribo- flavin Mg.	Niacin Mg.	Ascorbic Acid Mg.	Vita- min D I.U.
Men	25	65(143)	170(67)	3,200 ^b	65	0.8	12	5,000	1.6	1.6	16	75	
	45	65(143)	170(67)	2,900	65	0.8	12	5,000	1.5	1.6	15	75	
	65	65(143)	170(67)	2,600	65	0.8	12	5,000	1.3	1.6	13	75	
Women	25	55(121)	157(62)	2,300 ^b	55	0.8	12	5,000	1.2	1.4	12	70	
	45	55(121)	157(62)	2,100	55	0.8	12	5,000	1.1	1.4	11	70	
	65	55(121)	157(62)	1,800	55	0.8	12	5,000	1.0	1.4	10	70	
	Pregnant(3rd trimester)			Add 400	80	1.5	15	6,000	1.5	2.0	15	100	400
	Lactating(850 ml. daily)			Add 1,000	100	2.0	15	8,000	1.5	2.5	15	150	400
Infants ^c	0-1/12 ^d	(no specific recommendations)											
	1/12-3/12	6(13)	60(24)	kg.x 120	kg.x 3.5 ^e	0.6	6	1,500	0.3	0.4	3	30	400
	4/12-9/12	9(20)	70(28)	kg.x 110	kg.x 3.5 ^e	0.8	6	1,500	0.4	0.7	4	30	400
	10/12-1	10(22)	75(30)	kg.x 100	kg.x 3.5 ^e	1.0	6	1,500	0.5	0.9	5	30	400
Children	1-3	12(27)	87(34)	1,200	40	1.0	7	2,000	0.6	1.0	6	35	400
	4-6	18(40)	109(43)	1,600	50	1.0	8	2,500	0.8	1.2	8	50	400
	7-9	27(59)	129(51)	2,000	60	1.0	10	3,500	1.0	1.5	10	60	400
Boys	10-12	35(78)	144(57)	2,500	70	1.2	12	4,500	1.3	1.8	13	75	400
	13-15	49(108)	163(64)	3,200	85	1.4	15	5,000	1.6	2.1	16	90	400
	16-20	63(139)	175(69)	3,800	100	1.4	15	5,000	1.9	2.5	19	100	400
Girls	10-12	36(79)	144(57)	2,300	70	1.2	12	4,500	1.2	1.8	12	75	400
	13-15	49(108)	160(63)	2,500	80	1.3	15	5,000	1.3	2.0	13	80	400
	16-20	54(120)	162(64)	2,400	75	1.3	15	5,000	1.2	1.9	12	80	400

^aIn planning practical dietaries, the recommended allowances can be attained with a variety of common foods which will also provide other nutrient requirements less well known; the allowance levels are considered to cover individual variations among normal persons as they live in the United States subjected to ordinary environmental stresses.

^bThese calorie recommendations apply to the degree of activity for the reference man and woman described in the text.* For the urban "white collar" worker they are probably excessive. In any case, the calorie allowance must be adjusted to the actual needs of the individual as required to achieve and maintain his desirable weight.

^cThe recommendations for infants pertain to nutrients derived primarily from cow's milk. If the milk from which the protein is derived is human milk or has been treated to render it more digestible, the allowance may be in the range of 2-3 gm. protein per kg. There should be no question that human milk is a desirable source of nutrients for infants, even though it may not provide the levels recommended for certain nutrients.

^dDuring the first month of life desirable allowances for many nutrients are dependent upon maturation of excretory and endocrine functions. Therefore no specific recommendations are given.

* See Recommended Dietary Allowances, Revised 1953. Publication 302, National Academy of Sciences—National Research Council, Washington, D.C.

Table III(b). RECOMMENDED DAILY CALORIE ALLOWANCES FOR ADULTS BASED ON NATIONAL RESEARCH COUNCIL RECOMMENDED ALLOWANCES, 1953

Men										Women									
Age, Years	Weight		Calories per Day						Age Years	Weight		Calories per Day							
	Kg.	Lb.	Activities							Kg.	Lb.	Activities							
			"Standard"	Heavy	Sedentary	"Standard"	Heavy	Sedentary				"Standard"	Heavy	Sedentary					
25	50	110	2,600	3,175	2,025				25	40	88	1,800	2,200	1,400					
	60	132	3,000	3,675	2,350					50	110	2,100	2,575	1,650					
	65	143	3,200	3,925	2,500					55	121	2,300	2,850	1,800					
	70	154	3,400	4,175	2,650					60	132	2,400	2,950	1,875					
	80	176	3,700	4,525	2,875					70	154	2,700	3,300	2,100					
35	50	110	2,475	3,025	1,925				35	40	88	1,700	2,100	1,325					
	60	132	2,850	3,500	2,225					50	110	2,000	2,450	1,575					
	65	143	3,050	3,725	2,375					55	121	2,200	2,700	1,700					
	70	154	3,225	3,975	2,525					60	132	2,275	2,800	1,775					
	80	176	3,525	4,300	2,725					70	154	2,575	3,150	2,000					
45	50	110	2,350	2,875	1,825				45	40	88	1,625	2,000	1,250					
	60	132	2,700	3,325	2,125					50	110	1,900	2,325	1,500					
	65	143	2,900	3,550	2,250					55	121	2,075	2,575	1,625					
	70	154	3,075	3,775	2,400					60	132	2,175	2,650	1,675					
	80	176	3,350	4,075	2,600					70	154	2,450	3,000	1,900					
55	50	110	2,225	2,725	1,725				55	40	88	1,550	1,900	1,200					
	60	132	2,575	3,150	2,025					50	110	1,800	2,200	1,425					
	65	143	2,750	3,375	2,150					55	121	1,975	2,450	1,550					
	70	154	2,925	3,575	2,275					60	132	2,050	2,525	1,600					
	80	176	3,175	3,875	2,475					70	154	2,325	2,850	1,800					
65	50	110	2,125	2,600	1,650				65	40	88	1,475	1,800	1,150					
	60	132	2,450	3,000	1,925					50	110	1,700	2,100	1,350					
	65	143	2,600	3,200	2,025					55	121	1,875	2,325	1,475					
	70	154	2,775	3,400	2,150					60	132	1,950	2,400	1,525					
	80	176	3,025	3,675	2,350					70	154	2,200	2,700	1,700					
75	50	110	2,025	2,575	1,575				75	40	88	1,400		1,100					
	60	132	2,325	2,825	1,825					50	110	1,625		1,275					
	65	143	2,475	2,925	1,925					55	121	1,775		1,400					
	70	154	2,625	3,050	2,050					60	132	1,850		1,450					
	80	176	2,875	3,225	2,225					70	154	2,100		1,625					

Table III(c). RECOMMENDED DAILY DIETARY ALLOWANCES FOR ADULTS TWENTY-FIVE YEARS AND OVER ACCORDING TO CALORIE REQUIREMENTS^a EXPRESSED IN WEIGHTS

Calories	Protein	Calcium Mg.	Iron Mg.	Vitamin A I.U.	Thiamine Mg.	Ascorbic Acid		Riboflavin	
						Men Mg.	Women Mg.	Men Mg.	Women Mg.
1,400-2,000	^b	800	12	5000	1.0	75	70	1.6	1.4
2,100-2,200	^b	800	12	5000	1.1	75	70	1.6	1.4
2,300-2,400	^b	800	12	5000	1.2	75	70	1.6	1.4
2,500-2,600	^b	800	12	5000	1.3	75	70	1.6	1.4
2,700-2,800	^b	800	12	5000	1.4	75	70	1.6	1.4
2,900-3,100	^b	800	12	5000	1.5	75	70	1.6	1.4
3,200-3,700	^b	800	12	5000	1.6	75	70	1.6	1.4
3,800-4,200	^b	800	12	5000	1.7	75	70	1.6	1.4
4,300-4,500	^b	800	12	5000	1.8	75	70	1.6	1.4
1,200-1,400 (Reducing)	^b	800	12	5000	1.0	75	70	1.6	1.4

^a Based on 1953 recommendations of the Food and Nutrition Board of the National Research Council.

^b Recommended allowance for protein is 1 gram of protein per kilogram of body weight per day or 0.45 gram protein per pound of body weight per day.

**Table III(d). RECOMMENDED DAILY DIETARY ALLOWANCES^a FOR YOUNG MEN AND WOMEN
EIGHTEEN TO TWENTY-FOUR YEARS OF AGE INCLUSIVE EXPRESSED IN WEIGHTS**

	Age Years	Calories ^b	Protein Gm.	Calcium Mg.	Iron Mg.	Vitamin A I.U.	Thiamine Mg.	Ascorbic Acid Mg.	Riboflavin Mg.
Men	18	3,800	100	1,400	15	5,000	1.9	100	2.5
	19	3,800	100	1,400	15	5,000	1.9	100	2.5
	20	3,800	100	1,400	15	5,000	1.9	100	2.5
	21	3,800	100	1,400	15	5,000	1.9	100	2.5
	22	3,800	100	1,400	15	5,000	1.9	100	2.5
	23	3,600	90	1,250	14	5,000	1.8	90	2.0
	24	3,400	80	1,050	13	5,000	1.7	80	1.8
Women	18	2,400	75	1,300	15	5,000	1.2	80	1.9
	19	2,400	75	1,300	15	5,000	1.2	80	1.9
	20	2,400	75	1,300	15	5,000	1.2	80	1.9
	21	2,400	75	1,300	15	5,000	1.2	80	1.9
	22	2,400	75	1,300	15	5,000	1.2	80	1.9
	23	2,375	70	1,200	14	5,000	1.2	76	1.7
	24	2,350	60	1,050	13	5,000	1.2	72	1.5

^a Based on suggestions of the Food and Nutrition Board of the National Research Council, 1953.

^b Calories given are allowances for "standard" activity and should be adjusted for individual needs (see pages 53-56).

Table IV. NUTRITIVE VALUES OF FOODS IN WEIGHTS

The values given are for raw edible portions of food unless otherwise stated.
Vitamin values are given in International Units and in milligrams wherever possible.

A.P. means as purchased.

— means no appreciable amount.

A few values are stated within parentheses. This indicates that these values have been estimated.

The sources most frequently used in compiling this table of food values are listed below. Many sources giving values on fewer foods were also used but due to limitation of space are not listed.

Chatfield, C. *Food Composition Tables for International Use*. FAO Nutritional Studies No. 3 and No. 11, Food and Agriculture Organization of the United Nations (1949 and 1954).

Leung, W. W., Pecot, R. K., and Watt, B. K. *Composition of Foods Used in Far Eastern Countries*. Agriculture Handbook No. 34, U.S. Department of Agriculture (1952).

Sherman, H. C. *Chemistry of Food and Nutrition*, 8th edition. The Macmillan Company (1952).

Taylor, C. M. *Food Values in Shares and Weights*. The Macmillan Company (1942).

Taylor, C. M., and MacLeod, G. *Rose's Laboratory Handbook for Dietetics*, 5th edition. The Macmillan Company (1949).

Watt, B. K., and Merrill, A. L. *Composition of Foods—Raw, Processed, Prepared*. Agriculture Handbook No. 8. U.S. Department of Agriculture (1950).

Table IV. NUTRITIVE VALUES OF FOODS IN WEIGHTS

<i>Food</i>	<i>Weight</i> <i>Gm.</i>	<i>Oz.</i>	<i>Approximate Measure</i>	<i>Calo- ries</i>	<i>Pro- tein</i> <i>Gm.</i>	<i>Cal- cium</i> <i>Mg.</i>	<i>Iron</i> <i>Mg.</i>	<i>Vitamin</i> <i>A</i> <i>I.U.</i>	<i>Thia- mine</i> <i>Mg.</i>	<i>Ascorbic</i> <i>Acid</i> <i>Mg.</i>	<i>Ribo- flavin</i> <i>Mg.</i>
Almonds, shelled	28 100 17	1.0 3.5 0.6	(A.P. 1.9 oz.) ½ cup 12-15 nuts	170 597 100	5.3 18.6 3.2	72 254 43	1.2 4.4 0.7	0	0.07 0.25 0.04	Trace Trace Trace	0.19 0.67 0.11
Apples, raw	28 100 172	1.0 3.5 6.1	(A.P. 1.1 oz.) 1 small, 2½" diam. 1 large, 3½" diam.	16 58 100	0.1 0.3 0.5	2 6 10	0.1 0.3 0.5	26 90 155	0.01 0.04 0.07	1 5 9	0.01 0.03 0.05
Apricots, canned in syrup (solids and liquid)	28 100 125	1.0 3.5 4.4	4 medium halves, 2 tbsp. juice	23 80 100	0.2 0.6 0.8	3 10 13	0.1 0.3 0.4	383 1,350 1,688	0.01 0.02 0.03	1 4 5	0.01 0.02 0.03
Apricots, dried, sulfured	28 100 38	1.0 3.5 1.3	26 halves 10 halves	74 262 100	1.5 5.2 2.0	24 86 33	1.4 4.9 1.9	2,110 7,430 2,823	0.00 0.01 0.00	3 12 5	0.05 0.16 0.06
Apricots, raw	28 100 196	1.0 3.5 6.9	(A.P. 1.1 oz.) 5 apricots	14 51 100	0.3 1.0 2.0	5 16 31	0.1 0.5 1.0	792 2,790 5,468	0.01 0.03 0.06	2 7 14	0.01 0.05 0.10
Asparagus, raw	28 100 476	1.0 3.5 16.8	(A.P. 1.3 oz.) 12 stalks 57 stalks, 5" long	6 21 100	0.6 2.2 10.5	6 21 100	0.3 0.9 4.3	284 1,000 4,760	0.05 0.16 0.76	9 33 157	0.05 0.19 0.90
Asparagus, cooked	175	6.2	1 cup, cut spears	36	4.2	33	1.8	1,820	0.23	40	0.30
Avocado, raw	28 100 41	1.0 3.5 1.4	(A.P. 1.3 oz.) ½ pear ½ pear, 3½" long	70 245 100	0.5 1.7 0.7	3 10 4	0.2 0.6 0.2	82 290 119	0.02 0.06 0.02	5 16 7	0.04 0.13 0.05
Bacon, broiled, medium fat	16	0.6	2 to 3 slices	100	4.0	4	0.5	(0)	0.08	0	0.05
Bacon, medium fat, uncooked	28 100 16	1.0 3.5 0.6	(A.P. 1.0 oz.) 7 slices 1 slice, 8½" long	179 630 100	2.6 9.1 1.5	4 13 2	0.2 0.8 0.1	(0) (0) (0)	0.11 0.38 0.06	0 0 0	0.03 0.12 0.02
Bananas, raw	28 100 114	1.0 3.5 4.0	(A.P. 1.5 oz.) 1 medium, 6¾" long	25 88 100	0.3 1.2 1.4	2 8 9	0.2 0.6 0.7	122 430 490	0.01 0.04 0.05	3 10 11	0.01 0.05 0.06
Bean curd (see Soybean)	28 100 435	1.0 3.5 15.3	(A.P. 1.0 oz.) 1 cup 4½ cups	7 23 100	0.8 2.9 12.6	8 29 126	0.2 0.8 3.5	3 10 44	0.02 0.07 0.30	4 15 65	0.03 0.09 0.39

Table IV (Continued). NUTRITIVE VALUES OF FOODS IN WEIGHTS

<i>Food</i>	<i>Weight</i>		<i>Approximate Measure</i>	<i>Calo- ries</i>	<i>Pro- tein Gm.</i>	<i>Cal- cium Mg.</i>	<i>Iron Mg.</i>	<i>Vitamin A I.U.</i>	<i>Thia- mine Mg.</i>	<i>Ascorbic Acid Mg.</i>	<i>Ribo- flavin Mg.</i>
	<i>Gm.</i>	<i>Oz.</i>									
Beans, baked, canned *	28 100 80	1.0 3.5 2.8	$\frac{1}{2}$ cup, scant $\frac{3}{8}$ cup	36 125 100	1.6 5.8 4.6	16 56 45	0.6 2.1 1.7	9 30 24	0.01 0.05 0.04	1 2 2	0.01 0.04 0.03
* With pork and molasses.											
Beans, dried,* uncooked	28 100 29	1.0 3.5 1.0	$\frac{1}{2}$ cup $\frac{1}{8}$ cup	96 343 100	6.5 23.1 6.7	46 163 47	1.9 6.9 2.0	0 0 0	0.17 0.61 0.18	1 2 1	0.06 0.23 0.07
* Navy, kidney, pinto, red, pea, black, others.											
Beans, Lima, dried, uncooked	28 100 30	1.0 3.5 1.1	$\frac{3}{8}$ cup $\frac{1}{8}$ cup	95 333 100	5.9 20.7 6.2	19 68 20	2.1 7.5 2.3	0 0 0	0.14 0.48 0.14	1 2 1	0.05 0.18 0.05
Beans, Lima, raw	28 100 78	1.0 3.5 2.8	(A.P. 2.5 oz.) $\frac{1}{8}$ cup $\frac{1}{2}$ cup	36 128 100	2.1 7.5 5.9	9 31 24	0.7 2.3 1.8	109 385 300	0.07 0.25 0.20	11 40 31	0.05 0.18 0.14
Beans, Lima	160	5.6	1 cup cooked	152	8.0	46	2.7	460	0.22	24	0.14
Beans, snap, string, or green, raw	28 100 286	1.0 3.5 10.1	(A.P. 1.1 oz.) $\frac{3}{8}$ cup 2 $\frac{1}{2}$ cups, 1" pieces	10 35 100	0.7 2.4 6.9	18 65 186	0.3 1.1 3.1	227* 800* 2,288*	0.02 0.08 0.23	5 19 54	0.03 0.11 0.31
* Yellow about $\frac{1}{2}$ as much.											
Beans, snap	125	4.4	1 cup cooked	27	1.8	45	0.9	830	0.09	18	0.12
Beef, corned, canned, medium fat	28 100 46	1.0 3.5 1.6	$\frac{1}{2}$ cup 1 piece, 3" \times 2" \times $\frac{1}{2}$ "	61 216 100	7.2 25.3 11.6	6 20 9	1.2 4.3 2.0	(0) (0) (0)	0.01 0.02 0.01	0 0 0	0.07 0.24 0.11
Beef, dried or chipped	28 100 49	1.0 3.5 1.7	$\frac{1}{2}$ cup 4 thin slices, 4" \times 5"	58 203 100	9.7 34.3 16.8	6 20 10	1.4 5.1 2.5	(0) (0) (0)	0.03 0.11 0.05	0 0 0	0.06 0.22 0.11
Beef, round, lean, raw	28 100 62	1.0 3.5 2.2	(A.P. 1.0 oz.)* 1 piece, 2 $\frac{1}{2}$ " \times 1 $\frac{3}{4}$ " \times $\frac{3}{4}$ "	46 162 100	6.0 21.3 13.2	4 13 8	0.9 3.0 1.9	9 30 19	0.04 0.13 0.08	0 0 0	0.06 0.20 0.12
* Without bone.											
Beef, sirloin, roasted	28 100 34	1.0 3.5 1.2	2 slices 1 $\frac{1}{2}$ slices, 5" \times 2 $\frac{1}{2}$ " \times $\frac{1}{4}$ "	84 297 100	6.5 23.0 7.8	3 10 3	0.8 2.9 1.0	(0) (0) (0)	0.02 0.06 0.02	0 0 0	0.05 0.19 0.06

Table IV (Continued). NUTRITIVE VALUES OF FOODS IN WEIGHTS

<i>Food</i>	<i>Gm.</i>	<i>Weight Oz.</i>	<i>Approximate Measure</i>	<i>Calo- ries</i>	<i>Pro- tein Gm.</i>	<i>Cal- cium Mg.</i>	<i>Iron Mg.</i>	<i>Vitamin A I.U.</i>	<i>Thia- mine Mg.</i>	<i>Ascorbic Acid Mg.</i>	<i>Ribo- flavin Mg.</i>
Bread, rye and wheat	28 100 41	1.0 3.5 1.4	3½ slices 1½ slices, 3½" × 4" × ½"	69 244 100	2.6 9.1 3.7	20 72 30	0.5 1.6 0.7	0 0 0	0.04 0.14 0.06	0 0 0	0.02 0.08 0.03
Bread,* white, enriched	28 100 36 23	1.0 3.5 1.3 0.8	4½ slices 1½ slices, 4" × 3¾" × ½" 1 slice, 4" × 3¾" × ½"	78 275 100 63	2.4 8.5 3.1 2.0	22 79 28 18	0.5 1.8 0.6 0.4	0 0 0 0	0.07 0.24 0.09 0.06	0 0 0 0	0.04 0.15 0.05 0.04
<i>* 4% nonfat milk solids.</i>											
Bread,* white, unenriched	28 100 36	1.0 3.5 1.3	4½ slices 1½ slices, 4" × 3¾"	78 275 100	2.4 8.5 3.1	22 79 28	0.2 0.6 0.2	0 0 0	0.01 0.05 0.02	0 0 0	0.03 0.11 0.04
<i>* 4% nonfat milk solids.</i>											
Bread, white, raisin, enriched	28 100 35	1.0 3.5 1.2	3 slices 1 slice, 3¾" × 3½" × ½"	81 284 100	2.0 7.1 2.5	23 80 28	0.5* 1.8* 0.6*	3 10 4	0.07* 0.24* 0.08*	0 0 0	0.04* 0.15* 0.05*
<i>* For unenriched per 100 gm., iron 1.3, thiamine 0.07, and riboflavin 0.11.</i>											
Bread, whole wheat	28 100 42	1.0 3.5 1.5	1 slice 3½ slices 1½ slices, 3" × 3¾" × ½"	68 240 100	2.6 9.3 3.9	27 96 40	0.6 2.2 0.9	0 0 0	0.09 0.30 0.13	0 0 0	0.04 0.13 0.05
Broccoli, raw	28 100 345	1.0 3.5 12.2	(A.P. 1.6 oz.) 4 stalks, 5" long, stem, 1½" thick	8 29 100	0.9 3.3 11.4	37 130 449	0.4 1.3 4.5	1,704 6,000 20,700	0.03 0.10 0.35	34 118 407	0.06 0.21 0.72
Broccoli	150	5.3	1 cup cooked	44	5.0	195	2.0	5,100	0.10	111	0.22
Brussels sprouts, raw	28 100 213	1.0 3.5 7.5	(A.P. 1.3 oz.) 7 sprouts 15 sprouts, 1½" diam.	13 47 100	1.2 4.4 9.4	10 34 72	0.4 1.3 2.8	114 400 852	0.02 0.08 0.17	27 94 200	0.05 0.16 0.34
Brussels sprouts	130	4.6	1 cup cooked	60	5.7	44	1.7	520	0.05	61	0.16
Butter	28 100 14	1.0 3.5 0.5	½ cup, scant 1 tbsp.	203 716 100	0.2 0.6 0.1	6 20 3	0 0 0	937* 3,300* 462*	Trace Trace Trace	0 0 0	0.00 0.01 0.00
<i>* Based on year-round average of 15,000 I.U. per pound.</i>											

Table IV (Continued). NUTRITIVE VALUES OF FOODS IN WEIGHTS

Food	Weight		Approximate Measure	Calo- ries	Pro- tein Gm.	Cal- cium Mg.	Iron Mg.	Vitamin A I.U.	Thia- mine Mg.	Ascorbic Acid Mg.	Ribo- flavin Mg.
	Gm.	Oz.									
Buttermilk	(see Milk)										
Cabbage, Chinese, raw	28 100 714	1.0 3.5 25.2	(A.P. 1.4 oz.) ¾ cup, shredded ¾ medium head	4 14 100	0.3 1.2 8.6	12 43 307	0.3 0.9 6.4	74 260 1,856	0.01 0.03 0.21	9 31 221	0.01 0.04 0.29
Cabbage, headed, raw	28 100 417	1.0 3.5 14.7	(A.P. 1.4 oz.) 1½ cups, shredded 4½ cups, chopped	7 24 100	0.4 1.4 5.8	13 46 192	0.1 0.5 2.1	23* 80* 334*	0.02 0.06 0.25	14 50 209	0.01 0.05 0.21
* Loose leaf 10 times as much.											
Cabbage	170	6.0	1 cup cooked	40	2.4	78	0.8	150	0.08	53	0.08
Cantaloupes, raw	28 100 500	1.0 3.5 17.6	(A.P. 2.1 oz.) ¼ melon 1½ melons, 5" diam.	6 20 100	0.2 0.6 3.0	5 17 85	0.1 0.4 2.0	971* 3,420* 17,100*	0.01 0.05 0.25	9 33 165	0.01 0.04 0.20
* Based on dark yellow varieties.											
Carrots, raw	28 100 238	1.0 3.5 8.4	(A.P. 1.6 oz.) ¾ cup, ½" cubes 5 medium, 5" long	12 42 100	0.3 1.2 2.9	11 39 93	0.2 0.8 1.9	3,408 12,000 28,560	0.02 0.06 0.14	2 6 14	0.02 0.06 0.14
Carrots, cooked	145	5.1	1 cup, cubed	44	0.9	38	0.9	18,130	0.07	6	0.07
Cashew nuts	28 100 17	1.0 3.5 0.6	¾ cup 4 to 5 nuts	164 578 100	5.3 18.5 3.1	13 46 8	1.4 5.0 0.9	— — —	0.18 0.63 0.11	0 0 0	0.05 0.19 0.03
Cassava	(see Tapioca)										
Cauliflower, raw	28 100 400	1.0 3.5 14.1	(A.P. 2.2 oz.) 1 cup, small pieces 1 head, 4¾" diam.	7 25 100	0.7 2.4 9.6	6 22 88	0.3 1.1 4.4	26 90 360	0.03 0.11 0.44	20 69 276	0.03 0.10 0.40
Cauliflower	120	4.2	1 cup, cooked	30	2.9	26	1.3	108	0.07	34	0.10
Celery, bleached	28 100 556	1.0 3.5 19.6	(A.P. 1.6 oz.) ¾ cup 4½ cups, ½" pieces	5 18 100	0.4 1.3 7.2	14 50 278	0.1 0.5 2.8	0 0 0	0.01 0.05 0.28	2 7 39	0.01 0.04 0.22
Chard, Swiss, raw	28 100 476	1.0 3.5 16.8	(A.P. 1.2 oz.)	6 21 100	0.4 1.4 6.7	30* 105* 500*	0.7 2.5 11.9	795 2,800 13,328	0.02 0.06 0.29	11 38 181	0.02 0.07 0.33
* Availability doubtful.											

Table IV (Continued). NUTRITIVE VALUES OF FOODS IN WEIGHTS

<i>Food</i>	<i>Gm.</i>	<i>Weight Oz.</i>	<i>Approximate Measure</i>	<i>Calo- ries</i>	<i>Pro- tein Gm.</i>	<i>Cal- cium Mg.</i>	<i>Iron Mg.</i>	<i>Vitamin A I.U.</i>	<i>Thia- mine Mg.</i>	<i>Ascorbic Acid Mg.</i>	<i>Ribo- flavin Mg.</i>
Chard * Availability doubtful.	145	5.1	1 cup cooked	30	2.0	152 *	3.6	4,510	0.06	25	0.09
(see Cheese, Roquefort)											
Cheese, bleu	28	1.0	1" cube	113	7.1	248	0.3	398	0.01	(0)	0.12
Cheese, Cheddar	100	3.5	4 slices, 3½" × 3½" × ½"	398	25.0	873	1.0	1,400	0.02	(0)	0.42
	25	0.9	½ cup, scant, grated	100	6.3	218	0.3	350	0.01	(0)	0.11
Cheese, cottage (skim milk)	28	1.0		27	5.5	27	0.1	(6)	0.01	0	0.09
	100	3.5	5½ tbsp.	95	19.5	96	0.3	(20)	0.02	0	0.31
	105	3.7	½ cup, scant	100	20.5	101	0.3	(21)	0.02	0	0.33
Cheese, cream	28	1.0		105	2.6	19	0.1	(412)	(0.00)	(0)	0.06
	100	3.5	7 tbsp.	371	9.0	68	0.2	(1,450)	(0.01)	(0)	0.22
	27	1.0	2 tbsp.	100	2.4	18	0.1	(392)	(0.00)	(0)	0.06
Cheese, Parmesan	28	1.0		112	10.2	329	0.1	383	0.01	0	0.21
	100	3.5	1½ cups	393	36.0	1,160	0.4	1,350	0.03	0	0.73
	25	0.9	¾ cup	100	9.0	290	0.1	338	0.01	0	0.18
Cheese, Roquefort (blue mold, domestic)	28	1.0		105	6.1	89	0.3	(352)	0.01	0	0.17
	100	3.5	6½ tbsp.	368	21.5	315	1.0	(1,240)	0.03	0	0.61
	27	1.0	1½ tbsp.	100	5.8	85	0.3	(335)	0.01	0	0.16
Cheese, Swiss, processed	28	1.0		105	7.8	263	0.3	412	0.00	0	0.11
	100	3.5		370	27.5	925	0.9	1,450	0.01	0	0.40
	27	1.0	1 slice, 3½" × 3½" × ½"	100	7.4	250	0.2	392	0.00	0	0.11
Cherries, canned in syrup	28	1.0		21	0.2	3	0.1	(122)	0.01	1	0.01
	100	3.5		75	0.6	11	0.3	(430)	0.03	3	0.02
	133	4.7	½ cup	100	0.8	15	0.4	(572)	0.04	4	0.03
Cherries, red, sour, pitted, canned	28	1.0		14	0.2	3	(0.1)	204	0.01	2	0.01
	100	3.5	¾ cup	48	0.8	11	(0.3)	720	0.03	6	0.02
	208	7.3	¾ cup	100	1.7	23	(0.6)	1,498	0.06	12	0.04

Table IV (Continued). NUTRITIVE VALUES OF FOODS IN WEIGHTS

<i>Food</i>	<i>Weight</i> <i>Gm.</i>	<i>Oz.</i>	<i>Approximate Measure</i>	<i>Calo- ries</i>	<i>Pro- tein</i> <i>Gm.</i>	<i>Cal- cium</i> <i>Mg.</i>	<i>Iron</i> <i>Mg.</i>	<i>Vitamin</i> <i>A</i> <i>I.U.</i>	<i>Thia- mine</i> <i>Mg.</i>	<i>Ascorbic</i> <i>Acid</i> <i>Mg.</i>	<i>Ribo- flavin</i> <i>Mg.</i>
Collards	190	6.7	1 cup cooked	76	7.4	473	3.0	14,500	0.15	84	0.46
Corn, canned, drained solids	28 100 118	1.0 3.5 4.2	$\frac{1}{8}$ cup $\frac{1}{4}$ cup	24 85 100	0.8 2.7 3.2	1 5 6	0.2 0.6 0.7	65* 230* 271*	0.01 0.03 0.04	1 5 6	0.02 0.06 0.07
* Yellow; only a trace in white.											
Corn, canned, solids and liquid	256	9.0	1 cup	170*	5.1	10	1.3	520**	0.07	14	0.13
* For cream style, 208; changes in other nutrients insignificant. ** Yellow; only a trace in white.											
Corn, sweet, on cob, cooked	168	5.9	1 ear, 6" long	100	3.2	6	0.7	468*	0.13	10	0.12
* Yellow; only a trace in white.											
Corn flakes with added iron and thiamine	28 100 26	1.0 3.5 0.9	$4\frac{1}{4}$ cups $1\frac{1}{4}$ cups	109 385 100	2.3 8.1 2.1	3 10 3	0.6 2.2 0.6	(0) (0) (0)	0.12 0.43 0.11	0 0 0	0.03 0.10 0.03
Corn grits (see Hominy)											
Corn meal, de- germinated, en- riched	100 28 238	3.5 1.0 8.4	$\frac{3}{4}$ cup uncooked 3 tbsp. uncooked 1 cup cooked	363 100 119	7.9 2.2 2.6	6 2 2	2.9 0.8 1.0	300* 84* 100*	0.44 0.12 0.14	0 0 (0)	0.26 0.07 0.09
* Yellow; only a trace in white.											
Corn meal, degerminated, unenriched	100 28 238	3.5 1.0 8.4	$\frac{3}{4}$ cup uncooked 3 tbsp. uncooked 1 cup cooked	363 100 119	7.9 2.2 2.6	6 2 2	1.1 0.3 0.5	300* 84* 100*	0.16 0.04 0.04	0 0 (0)	0.08 0.02 0.02
* Yellow; only a trace in white.											
Crab meat, canned	28 100 96	1.0 3.5 3.4	$\frac{1}{8}$ cup	30 104 100	4.8 16.9 16.2	13 45 43	0.3 0.9 0.9	— — —	0.07 0.23 0.22	0 0 0	0.04 0.15 0.14
Crackers, Graham or whole wheat	28 100 25	1.0 3.5 0.9	$10\frac{1}{2}$ crackers $2\frac{1}{2}$ crackers, $2\frac{1}{2}'' \times 2\frac{3}{4}''$	112 393 100	2.3 8.0 2.0	6 20 5	0.5 1.9 0.5	(0) (0) (0)	0.09 0.30 0.08	0 0 0	0.03 0.12 0.03
Crackers, oyster	28 100	1.0 3.5	1 cup 100 crackers	119 430	2.7 10.0	6 20	0.3 1.0	(0) (0)	0.02 0.10	(0) (0)	0.01 0.04

Table IV (Continued). NUTRITIVE VALUES OF FOODS IN WEIGHTS

<i>Food</i>	<i>Weight</i> <i>Gm.</i>	<i>Oz.</i>	<i>Approximate Measure</i>	<i>Calo- ries</i>	<i>Pro- tein</i> <i>Gm.</i>	<i>Cal- cium</i> <i>Mg.</i>	<i>Iron</i> <i>Mg.</i>	<i>Vitamin</i> <i>A</i> <i>I.U.</i>	<i>Thia- mine</i> <i>Mg.</i>	<i>Ascorbic</i> <i>Acid</i> <i>Mg.</i>	<i>Ribo- flavin</i> <i>Mg.</i>
Crackers, saltines	28 100 23	1.0 3.5 0.8	25 crackers 6 crackers, 2" square	122 431 100	2.6 9.2 2.1	5 19 4	0.3 1.0 0.2	(0) (0) (0)	0.02 0.06 0.01	(0) (0) (0)	0.01 0.04 0.01
Cranberries, raw	28 100 208	1.0 3.5 7.3	(A.P. 1.0 oz.) $\frac{1}{4}$ cup 1 $\frac{1}{8}$ cups	14 48 100	0.1 0.4 0.8	4 14 29	0.2 0.6 1.2	11 40 83	(0.01) (0.03) (0.06)	3 12 25	(0.01) (0.04) (0.08)
Cranberry sauce (whole), canned	28 100 51	1.0 3.5 1.8	$\frac{1}{2}$ cup 3 tbsp.	56 198 100	0.0 0.1 0.1	(2) (8) (4)	(0.1) (0.3) (0.2)	9 30 15	(0.01) (0.02) (0.01)	1 2 1	(0.01) (0.02) (0.01)
Cream, heavy, whipping	28 100 30	1.0 3.5 1.1	$\frac{1}{2}$ cup 2 tbsp.	94 330 100	0.7 2.3 0.7	22 78 23	0.0 0.0 0.0	559 1,970 591	0.01 0.02 0.01	0 1 0	0.03 0.11 0.03
Cream, light, coffee	28 100 49	1.0 3.5 1.7	$\frac{1}{2}$ cup 3 tbsp.	58 204 100	0.8 2.9 1.4	28 97 48	0.0 0.1 0.0	236 830 407	0.01 0.03 0.01	0 1 0	0.04 0.14 0.07
Cucumbers, raw	28 100 833	1.0 3.5 29.4	(A.P. 1.4 oz.) 12 slices, $\frac{1}{8}$ " thick 3 cucumbers, 7 $\frac{1}{2}$ " long, 2" diam.	3 12 100	0.2 0.7 5.8	3 10 83	0.1 * 0.3 * 2.5 *	0 * 0 * 0 *	0.01 0.04 0.33	2 8 67	0.03 0.12 1.00
* For pared cucumbers; unpared, about 1.2 mg. iron and 260 I.U. vitamin A per 100 gm.											
Dandelion greens, raw	28 100 227	1.0 3.5 8.0	(A.P. 1.9 oz.) 5 $\frac{1}{4}$ cups	12 44 100	0.8 2.7 6.1	43 150 341	0.9 3.1 7.0	(2,840) (10,000) (22,700)	0.05 0.19 0.43	7 23 52	0.04 0.14 0.32
Dandelion greens	140	4.9	1 cup cooked	62	3.8	211	4.3	(21,433)	0.19	23	0.17
Dasheen (see Yautia)	28 100 35	1.0 3.5 1.2	14 dates 5 dates	81 284 100	0.6 2.2 0.8	20 72 25	0.6 2.1 0.7	51 180 63	0.02 0.08 0.03	0 0 0	0.01 0.05 0.02
Dates, "fresh" and dried, stoned	28 100 417	1.0 3.5 14.7	(A.P. 1.1 oz.) 7 slices, 4" diam., $\frac{1}{2}$ " thick	7 24 100	0.3 1.1 4.6	4 15 63	0.1 0.4 1.7	17 60 250	0.02 0.07 0.29	2 7 29	0.02 0.06 0.25
Eggplant, raw	28 100 417	1.0 3.5 14.7	(A.P. 1.1 oz.) 7 slices, 4" diam., $\frac{1}{2}$ " thick	7 24 100	0.3 1.1 4.6	4 15 63	0.1 0.4 1.7	17 60 250	0.02 0.07 0.29	2 7 29	0.02 0.06 0.25

Table IV (Continued). NUTRITIVE VALUES OF FOODS IN WEIGHTS

Food	Weight Gm.	Oz.	Approximate Measure	Calo- ries	Pro- tein Gm.	Cal- cium Mg.	Iron Mg.	Vitamin A I.U.	Thia- mine Mg.	Ascorbic Acid Mg.	Ribo- flavin Mg.
Eggs, whole, raw	28 100 62	1.0 3.5 2.2	(A.P. 1.1 oz.) 1½ eggs	46 162 100	3.6 12.8 7.9	15 54 33	0.8 2.7 1.7	426 1,500 930	0.03 0.10 0.06	0 0 0	0.11 0.37 0.23
Eggs, whole, cooked	53	1.9	1 egg in shell	75	6.0	25	1.3	539	0.04	0	0.13
Eggs, white only, raw	28 100 200	1.0 3.5 7.1	3½ whites 6½ whites	14 50 100	3.1 10.8 21.6	3 11 22	0.0 0.1 0.2	(0) (0) (0)	0 0 0	0 0 0	0.07 0.23 0.46
Eggs, yolk only, raw	100 28	3.5 1.0	6 yellow, medium 2 yolks, small	361 100	16.3 4.6	157 44	7.2 2.0	3,750 1,050	0.30 0.08	0 0	0.45 0.13
Escarole and endive, raw	28 100 500	1.0 3.5 17.6	(A.P. 1.9 oz.)	6 20 100	0.5 1.6 8.0	22 79 395	0.5 1.7 8.5	(2,840) (10,000) (50,000)	* 0.02 * 0.08 * 0.40	3 11 55	0.09 0.33 1.65
* Bleached varieties, little or no vitamin A value.											
(see Wheat meal)											
Farina, dark	28 100 27 240	1.0 3.5 1.0 8.5	½ cup uncooked 2½ tbsp. uncooked 1 cup cooked	105 370 100 104	3.1 10.9 2.9 3.1	6 21 6 7	0.4 1.3 0.4 0.5	(0) (0) (0) 0	0.11 0.37 0.10 0.10	0 0 0 (0)	0.07 0.26 0.07 0.07
Farina, white, unenriched	28 100 27 240	1.0 3.5 1.0 8.5	½ cup uncooked 2½ tbsp. uncooked 1 cup cooked	105 370 100 104	3.1 10.9 2.9 3.1	6 21 6 7	0.3 1.0 0.3 0.2	(0) (0) (0) 0	0.02 0.06 0.02 0.01	0 0 0 (0)	0.02 0.06 0.02 0.02
Figs, dried	28 100 37	1.0 3.5 1.3	6 medium 2 medium	77 270 100	1.1 4.0 1.5	53 186 69	0.8 2.9 1.1	20 70 26	0.04 0.13 0.05	0 0 0	0.03 0.11 0.04
Figs, raw	28 100 127	1.0 3.5 4.5	(A.P. 1.0 oz.) 2½ small 3½ small, 1½" diam.	22 79 100	0.4 1.4 1.8	15 54 69	0.2 0.6 0.8	21 75 95	0.02 0.08 0.10	1 2 3	0.02 0.06 0.08
Fish, bluefish, raw	28 100	1.0 3.5	(A.P. 2.0 oz.) 1 piece, 3" × 2½" × 1"	35 124	5.8 20.5	7 23	0.2 0.6	— —	0.02 0.07	(1) (2)	0.02 0.07
Fish, bluefish	50	1.8	1 piece, 3½" × 1" × ½" fried	102	11.3	9	0.3	—	0.05	—	0.05
Fish, cod, raw	28 100 135	1.0 3.5 4.8	(A.P. 1.4 oz.) 1 piece, 4" × 2½" × 1"	21 74 100	4.7 16.5 22.3	3 10 14	0.3 0.9 1.2	0 0 0	0.02 0.06 0.08	1 2 3	0.03 0.09 0.12

Table IV (Continued). NUTRITIVE VALUES OF FOODS IN WEIGHTS

Food	Weight		Approximate Measure	Calo- ries	Pro- tein Gm.	Cal- cium Mg.	Iron Mg.	Vitamin A I.U.	Thia- mine Mg.	Ascorbic Acid Mg.	Ribo- flavin Mg.
	Gm.	Oz.									
Fish, cod, salted	28 100 77	1.0 3.5 2.7		37 130 100	8.2 29.0 22.3	2 8 6	0.1 0.3 0.2	0 0 0	0.01 0.02 0.02	(0) (0) (0)	0.02 0.07 0.05
Fish, flounder, raw	28 100 147	1.0 3.5 5.2	(A.P. 2.5 oz.) 1 piece, 4" × 2½" × 1"	19 68 100	4.2 14.9 21.9	11 40 59	0.2 0.8 1.2	— — —	0.02 0.06 0.09	— — —	0.01 0.05 0.07
Fish, haddock, raw	28 100	1.0 3.5	(A.P. 2.1 oz.) 1 section, 1½" on back	22 79	5.2 18.2	7 23	0.2 0.7	1 5	0.01 0.05	0 0	0.02 0.08
Fish, haddock	63	2.2	1 piece, 3" × 2½" × ½", fried	100	11.8	11	0.4	—	0.03	—	0.06
Fish, halibut steak, raw	28 100	1.0 3.5	(A.P. 1.2 oz.) 1 piece, 3" × 1½" × 1"	36 126	5.3 18.6	4 13	0.2 0.7	125 440	0.02 0.07	0 0	0.02 0.06
Fish, halibut	55	1.9	1 piece, 3" × 1½" × ½", broiled	100	14.4	8	0.4	0	0.03	—	0.04
Fish, mackerel, raw	28 100	1.0 3.5	(A.P. 1.9 oz.) 1 section, 4½" on back	53 188	5.3 18.7	3 10	0.3 1.0	(128) (450)	0.04 0.15	— —	0.10 0.35
Fish, salmon, canned	28 100 49	1.0 3.5 1.7	¾ cup ½ cup	58 203 100	5.6 19.7 9.7	44 154 75	0.3 0.9 0.4	65 230 113	0.01 0.03 0.01	0 0 0	0.04 0.14 0.07
Fish, salmon, raw	28 100	1.0 3.5	(A.P. 1.1 oz.) 2 slices, 3" × 2" × ¾"	63 220	5.7 20.0	6* 20*	0.3 1.1	85 300	0.05 0.17	3 9	0.06 0.19
* Bone excluded; with bone included, about 13 times as much.											
Fish, salmon	60	2.1	1 slice, 3" × 2" × ½", broiled	100	9.1	10	0.5	137	0.08	4	0.08
Fish, sardines, drained solids	28 100 47	1.0 3.5 1.7	10 sardines 5 sardines, 3" long	61 214 100	7.3 25.7 12.1	110 386 181	1.0 3.5 1.6	62 220 103	0.01 0.02 0.01	0 0 0	0.05 0.17 0.08
Fish, shad, raw	28 100 60	1.0 3.5 2.1	(A.P. 2.1 oz.) 1 section, 2½" long	48 168 100	5.3 18.7 11.2	6 20 12	0.1 0.5 0.3	36 125 75	0.03 0.09 0.05	0 0 0	0.07 0.24 0.14
Fish, swordfish, raw	28 100	1.0 3.5	(A.P. 1.0 oz.) 1 slice, 3" × 3" × ¾"	34 118	5.5 19.2	5 19	0.3 0.9	449 1,580	0.01 0.05	— —	0.01 0.05

Table IV (Continued). NUTRITIVE VALUES OF FOODS IN WEIGHTS

<i>Food</i>	<i>Gm.</i>	<i>Weight Oz.</i>	<i>Approximate Measure</i>	<i>Calo- ries</i>	<i>Pro- tein Gm.</i>	<i>Cal- cium Mg.</i>	<i>Iron Mg.</i>	<i>Vitamin A I.U.</i>	<i>Thia- mine Mg.</i>	<i>Ascorbic Acid Mg.</i>	<i>Ribo- flavin Mg.</i>
Fish, sword- fish	56	2.0	1 slice, 3" × 1½" × ½", broiled	100	15.4	11	0.6	1,296	0.03	(0)	0.03
Fish, tuna, canned, drained	28 100 51	1.0 3.5 1.8	½ cup ½ cup	56 198 100	8.2 29.0 14.8	10 34 17	0.5 1.7 0.9	20 70 36	0.01 0.04 0.02	0 0 0	0.04 0.13 0.07
Flounder (see Fish)											
Flour, rye, light	100 28	3.5 1.0	¾ cup 3 tbsp.	357 100	9.4 2.6	22 6	1.3 0.4	(0) (0)	0.15 0.04	0 0	0.07 0.02
Flour, wheat, 80% extraction	100 28	3.5 1.0	¾ cup	359 100	12.0 3.4	24 7	1.3 0.4	(0) (0)	0.26 0.07	(0) (0)	0.07 0.02
Flour, wheat, white, en- riched	28 100 27	1.0 3.5 1.0	¾ cup, sifted 4 tbsp., sifted	103 364 100	3.0 10.5 2.8	5 16 4	0.8 2.9 0.8	0 0 0	0.12 0.44 0.12	0 0 0	0.07 0.26 0.07
Flour, wheat, white, unen- riched	28 100 27	1.0 3.5 1.0	¾ cup, sifted 4 tbsp., sifted	103 364 100	3.0 10.5 2.8	5 16 4	0.4 1.3 0.4	0 0 0	0.02 0.08 0.02	0 0 0	0.01 0.04 0.01
Flour, whole wheat	28 100 30	1.0 3.5 1.1	¾ cup, scant 3 tbsp., unsifted	95 333 100	3.8 13.3 4.0	12 41 12	1.1 3.9 1.2	7 23 7	0.16 0.55 0.17	0 0 0	0.04 0.15 0.05
French dressing	15	0.5	1 tbsp.	92	0	0	0.0	0	0	0	0
Garbanzos or chick- peas, dried, un- cooked	100 28	3.5 1.0	½ cup, scant ½ cup	359 100	20.8 5.9	92 26	7.1 2.0	Trace Trace	0.55 0.15	(2) (1)	0.17 0.05
Grapefruit, raw	28 100 250	1.0 3.5 8.8	(A.P. 1.5 oz.) ½ cup, sections ½ large, 5" diam.	11 40 100	0.1 0.5 1.3	6 22 55	0.1 0.3 0.8	6 20 50	0.02 0.08 0.20	11 40 100	0.02 0.06 0.15
Grapefruit juice, unsweetened, fresh or canned	28 100 263	1.0 3.5 9.3	½ cup, scant 1½ cups	11 38 100	0.1 0.5 1.3	3 10 26	0.1 0.3 0.8	6 20 53	0.02 0.08 0.21	11 40 105	0.02 0.06 0.16
Grape juice, Concord	28 100 149	1.0 3.5 5.3	½ cup, scant ¾ cup	19 67 100	0.1 0.4 0.6	3 10 15	0.1 0.3 0.4	0 0 0	0.01 0.04 0.06	1 2 3	0.01 0.05 0.07

Table IV (Continued). NUTRITIVE VALUES OF FOODS IN WEIGHTS

Food	Weight		Approximate Measure	Calo- ries	Pro- tein Gm.	Cal- cium Mg.	Iron Mg.	Vitamin A I.U.	Thia- mine Mg.	Ascorbic Acid Mg.	Ribo- flavin Mg.
	Gm.	Oz.									
Grapes, adherent skin	28 100 152	1.0 3.5 5.4	(A.P. 1.0 oz.) 20 to 25 grapes 30 to 35 grapes	19 66 100	0.2 0.8 1.2	5 17 26	0.2 0.6 0.9	14 50 76	0.01 0.04 0.06	1 4 6	0.01 0.04 0.06
Guavas, raw	28 100 143	1.0 3.5 5.0	(A.P. 1.1 oz.) 2 guavas	20 70 100	0.3 1.0 1.4	5 16 23	0.3 0.9 1.3	57 200 286	0.02 0.06 0.09	85 300 429	0.01 0.04 0.06
Haddock (see Fish)											
Halibut (see Fish)											
Halibut liver oil	11	0.4	1 tbsp.	100	0	0	0	*	0	0	0
* For vitamin A value, see statement on container.											
Ham, smoked, boiled, lean only	28 100 35	1.0 3.5 1.2	2 slices, 5" × 5" × $\frac{1}{8}$ " 1 slice, 5" × 3 $\frac{1}{2}$ " × $\frac{1}{8}$ "	82 288 100	6.6 23.1 8.1	5 17 6	0.7 2.6 0.9	(0) (0) (0)	0.34 1.20 0.42	0 0 0	0.08 0.27 0.09
Ham, smoked, medium fat, raw	28 100 26	1.0 3.5 0.9	(A.P. 1.0 oz.)* $\frac{1}{2}$ slice, 5 $\frac{1}{2}$ " diam., $\frac{1}{2}$ " thick	110 389 100	4.8 16.9 4.4	3 10 3	0.7 2.5 0.7	(0) (0) (0)	0.20 0.70 0.18	0 0 0	0.05 0.19 0.05
* Without bone.											
Ham, smoked, medium fat	200	7.0	1 slice cooked, 5 $\frac{1}{2}$ " diam., $\frac{1}{8}$ " thick	800	46.0	20	5.8	(0)	1.08	0	0.42
Hamburger (see Beef, round)											
Hominy (corn grits), enriched * Yellow; only a trace in white.	100 28 242	3.5 1.0 8.5	3 tbsp. 1 cup cooked	362 100 122	8.7 2.4 2.9	4 1 2	2.9 0.8 0.7	300* 84* 100*	0.44 0.12 0.11	0 0 (0)	0.26 0.07 0.08
Hominy (corn grits), unenriched * Yellow; only a trace in white.	100 28	3.5 1.0	3 tbsp.	362 100	8.7 2.4	4 1	1.0 0.3	300* 84*	0.13 0.04	0 0	0.04 0.01
Honey, strained	28 100 34	1.0 3.5 1.2	$\frac{1}{4}$ cup 1 tbsp., rounded	83 294 100	0.1 0.3 0.1	1 5 2	0.3 0.9 0.3	(0) (0) (0)	Trace Trace Trace	1 4 1	0.01 0.04 0.01

Table IV (Continued). NUTRITIVE VALUES OF FOODS IN WEIGHTS

Food	Weight		Approximate Measure	Calo- ries	Pro- tein Gm.	Cal- cium Mg.	Iron Mg.	Vitamin A I.U.	Thia- mine Mg.	Ascorbic Acid Mg.	Ribo- flavin Mg.
	Gm.	Oz.									
Honeydew melon, raw	28	1.0	(A.P. 1.6 oz.)	9	0.1	(5)	(0.1)	11	0.01	7	0.01
	100	3.5	$\frac{1}{4}$ cup, balls	32	0.5	(17)	(0.4)	40	0.05	23	0.03
	313	11.0	2 wedges, 2" \times 7"	100	1.6	(53)	(1.3)	125	0.16	72	0.09
Ice cream, plain	28	1.0		59	1.1	35	0.0	148	0.01	0	0.05
	100	3.5		207	4.0	123	0.1	520	0.04	1	0.19
	48	1.7	$\frac{1}{4}$ cup	100	1.9	59	0.0	250	0.02	0	0.09
Jams, marmalades, etc.	28	1.0		79	0.1	3	0.1	3	0.01	2	0.01
	100	3.5	5 tbsp.	278	0.5	12	0.3	10	0.02	6	0.02
	36	1.3	$1\frac{1}{4}$ tbsp.	100	0.2	4	0.1	4	0.01	2	0.01
Jellies	28	1.0		72	0.1	(3)	(0.1)	(3)	(0.01)	1	(0.01)
	100	3.5	5 tbsp.	252	0.2	(12)	(0.3)	(10)	(0.02)	4	(0.02)
	40	1.4	2 tbsp.	100	0.1	(5)	(0.1)	(4)	(0.01)	2	(0.01)
Kale, raw	28	1.0	(A.P. 1.6 oz.)	11	1.1	64	0.7	(2,840)	0.05	34	0.09
	100	3.5		40	3.9	225	2.5	(10,000)	0.16	118	0.33
	250	8.8	5 $\frac{1}{4}$ cups	100	9.8	563	6.3	(25,000)	0.40	295	0.83
Kale	110	3.9	1 cup cooked	45	4.3	248	2.4	9,220	0.08	56	0.25
Kidney, beef, raw	28	1.0	(A.P. 1.0 oz.)	40	4.3	3	2.2	327	0.11	4	0.72
	100	3.5	$\frac{1}{4}$ cup, cubed	141	15.0	9	7.9	1,150	0.37	13	2.55
	71	2.5	$\frac{1}{4}$ cup, cubed	100	10.7	6	5.6	817	0.26	9	1.81
Kohlrabi, raw	28	1.0	(A.P. 1.9 oz.)	9	0.6	13	0.2	Trace	0.02	17	0.01
	100	3.5	$\frac{1}{4}$ cup	30	2.1	46	0.6	Trace	0.06	60	0.05
	333	11.7	2 $\frac{3}{4}$ cups, $\frac{1}{2}$ " cubes	100	7.0	153	2.0	Trace	0.20	200	0.17
Kohlrabi	155	5.5	1 cup cooked	47	3.3	71	0.9	Trace	0.06	57	0.06
Lamb, leg, roasted	28	1.0		78	6.8	3	0.9	0	0.04	0	0.07
	100	3.5		274	24.0	10	3.1	0	0.14	0	0.25
	36	1.3	1 slice, 3 $\frac{1}{2}$ " \times 3" \times $\frac{1}{4}$ "	100	8.6	4	1.1	0	0.05	0	0.09
Lamb, rib chop, medium fat	28	1.0	(A.P. 1.3 oz.)	101	4.2	3	0.6	(0)	0.04	0	0.05
	100	3.5	1 chop raw	356	14.9	9	2.2	(0)	0.13	0	0.18
	85	3.0	1 chop broiled	356	20.0	9	2.6	(0)	0.12	0	0.22
Lard	14	0.5	1 tbsp.	126	0	0	0	0	0	0	0
Lemon juice	14	0.5	1 tbsp.	3	0.1	3	0.0	0	0.01	7	0.00

Table IV (Continued). NUTRITIVE VALUES OF FOODS IN WEIGHTS

Food	Weight		Approximate Measure	Calo- ries	Pro- tein Gm.	Cal- cium Mg.	Iron Mg.	Vitamin A I.U.	Thia- mine Mg.	Ascorbic Acid Mg.	Ribo- flavin Mg.
	Gm.	Oz.									
Lentils, dried, split	28	1.0		96	6.8	10	2.1	162	0.16	1	0.07
	100	3.5	$\frac{1}{2}$ cup	339	24.0	34	7.4	570	0.56	5	0.24
	29	1.0	2 tbsp.	100	7.0	10	2.1	165	0.16	1	0.07
Lettuce, headed	28	1.0	(A.P. 1.4 oz.)	4	0.3	6	0.1	109	0.02	3	0.02
	100	3.5	5 large leaves	15	1.2	22	0.5	385	0.07	11	0.06
	667	23.5	1 $\frac{1}{2}$ heads, 4 $\frac{1}{2}$ " diam.	100	8.0	147	3.3	2,568	0.47	73	0.40
Lettuce, loose leaf and Ro- maine	28	1.0	3 leaves, 8" long	4	0.3	18	0.3	1,093	0.02	3	0.04
	100	3.5	$\frac{1}{2}$ head, 4" diam.	15	1.2	62	1.1	3,850	0.07	11	0.15
Liver, beef, raw	28	1.0	(A.P. 1.0 oz.)	39	5.6	2	1.9	12,468	0.07	9	0.95
	100	3.5		136	19.7	8	6.6	43,900	0.26	31	3.33
	74	2.6	1 piece, 3" \times 3" \times $\frac{1}{2}$ "	100	14.6	6	4.9	32,280	0.19	23	2.46
Liver, beef, fried	100	3.5	1 piece, 3" \times 3" \times $\frac{1}{4}$ "	207	23.5	9	7.8	53,500	0.26	31	3.94
Liver, calf, raw	114	4.0		160	21.5	7	12.0	25,443	0.24	40	3.52
Liver, chicken, raw	114	4.0		160	25.0	19	8.4	36,402	0.23	23	2.79
Liver, pork, raw	114	4.0		152	22.2	11	20.3	16,053	0.45	25	3.36
Liver, lamb, raw	114	4.0		154	23.7	9	14.2	57,097	0.43	37	3.71
Liverwurst	(see Sausage, liver)										
Lobster, boiled or canned	28	1.0	(A.P. 2.8 oz.)*	26	5.2	18	0.2	43	(0.01)	—	0.02
	100	3.5		92	18.4	65	0.8	150	(0.05)	—	0.07
	109	3.8	$\frac{3}{4}$ cup	100	20.1	71	0.9	164	(0.05)	—	0.08
* Whole.											
Loganberries, raw	28	1.0	(A.P. 1.0 oz.)	18	0.3	10	0.3	9	0.01	7	(0.02)
	100	3.5	$\frac{3}{4}$ cup	62	1.0	35	1.2	33	0.03	24	(0.07)
	161	5.7	1 $\frac{1}{4}$ cups	100	1.6	56	1.9	53	0.05	39	(0.11)
Macaroni, enriched, uncooked	28	1.0		107	3.6	6	0.8	(0)	0.25	0	0.11
	100	3.5	10 sticks, 9" long	377	12.8	22	2.9	(0)	0.88	0	0.37
	27	1.0	$\frac{1}{4}$ cup, 1" pieces	100	3.5	6	0.8	(0)	0.24	0	0.10
Macaroni, enriched	172	6.1	1 cup cooked	200	6.8	12	1.4	(0)	0.23	(0)	0.14

Table IV (Continued). NUTRITIVE VALUES OF FOODS IN WEIGHTS

Food	Weight Gm.	Oz.	Approximate Measure	Calo- ries	Pro- tein Gm.	Cal- cium Mg.	Iron Mg.	Vitamin A I.U.	Thia- mine Mg.	Ascorbic Acid Mg.	Ribo- flavin Mg.
Macaroni, unenriched, uncooked	28 100 27	1.0 3.5 1.0	10 sticks, 9" long ½ cup, 1" pieces	107 377 100	3.6 12.8 3.5	6 22 6	0.4 1.5 0.4	(0) (0) (0)	0.03 0.09 0.02	0 0 0	0.02 0.06 0.02
Mackerel (see Fish)											
Mangoes, raw	28 100 152	1.0 3.5 5.4	(A.P. 1.5 oz.) ½ medium	19 66 100	0.2 0.7 1.1	3 9 14	0.1 0.2 0.3	1,803 6,350 9,652	0.02 0.06 0.09	12 41 62	0.02 0.06 0.09
Margarine	28 100 14	1.0 3.5 0.5	1 tbsp.	204 720 100	0.2 0.6 0.1	6 21 3	0.0 0.0 0.0	937* 3,300* 462*	0.00 0.01 0.00	0 0 0	0.01 0.03 0.00
* Based on addition of 15,000 I.U. per pound.											
Mayonnaise	14	0.5	1 tbsp.	100	0.2	2	0.1	35	0.00	0	0.01
Milk, buttermilk, cultured *	28 100 278 244	1.0 3.5 9.8 8.6	1½ cups 1 cup	10 36 100 86	1.0 3.5 9.7 8.5	34 118 328 288	0.0 0.1 0.3 0.2	1 3 11 10	0.01 0.04 0.11 0.09	0 1 3 3	0.05 0.18 0.50 0.43
* Made from skim milk.											
Milk, chocolate drink, commercial	244	8.6	1 cup	146	8.5	295	0.3	10	0.08	3	0.43
Milk, condensed, sweetened	28 100 31	1.0 3.5 1.1	½ cup 1½ tbsp.	91 320 100	2.3 8.1 2.5	78 273 85	0.1 0.2 0.1	(122) (430) (133)	0.01 0.05 0.02	0 1 0	0.11 0.39 0.12
Milk, evaporated, unsweetened	28 100 72 252	1.0 3.5 2.5 8.9	½ cup 4½ tbsp. 1 cup	39 138 100 348	2.0 7.0 5.0 17.6	69 243 175 612	0.1 0.2 0.1 0.5	114 400 288 1,008	0.02 0.07 0.05 0.18	0 1 1 3	0.10 0.36 0.26 0.91
Milk, goat	244	8.6	1 cup	164	8.1	315	0.2	(390)	0.10	2	0.26
Milk, malted, dry	28 100 25	1.0 3.5 0.9	½ cup 3 tbsp.	116 407 100	4.1 14.6 3.7	82 287 72	0.6 2.1 0.5	290 1,020 255	0.10 0.34 0.09	(0) (0) (0)	0.14 0.50 0.13
Milk, skim, dried	100 28	3.5 1.0	½ cup 3½ tbsp.	362 100	35.6 10.0	1,300 364	0.6 0.2	(40) (11)	0.35 0.10	7 2	1.96 0.55

Table IV (Continued). NUTRITIVE VALUES OF FOODS IN WEIGHTS

Food	Weight Gm.	Oz.	Approximate Measure	Calo- ries	Pro- tein Gm.	Cal- cium Mg.	Iron Mg.	Vitamin A I.U.	Thia- mine Mg.	Ascorbic Acid Mg.	Ribo- flavin Mg.
Milk, skim, fluid	28 100 278 246	1.0 3.5 9.8 8.7	$\frac{3}{8}$ cup 1 $\frac{1}{8}$ cups 1 cup	10 36 100 87	1.0 3.5 9.7 8.6	35 122 339 303	0.0 0.1 0.3 0.2	(1) (4) (12) (10)	0.01 0.05 0.14 0.12	1* 2* 6* 5*	0.05 0.18 0.50 0.44
* Pasteurized.											
Milk, whole, fluid, cow's	28 100 147 244 976	1.0 3.5 5.2 8.6 34.4	$\frac{3}{8}$ cup $\frac{3}{8}$ cup 1 cup 1 quart	19 68 100 166 666	1.0 3.5 5.1 8.5 34.2	34 118 173 288 1,152	0.0 0.1 0.1 0.2 0.7	55 195 287 476 1,903	0.01 0.04 0.06 0.09 0.35	1* 2* 3* 5* 20*	0.05 0.18 0.26 0.44 1.76
* Pasteurized.											
Molasses, cane, medium	28 100 43	1.0 3.5 1.5	4 $\frac{1}{2}$ tbsp. 2 tbsp.	66 232 100	(0) (0) (0)	82 290 125	1.7 6.0 2.6	(0) (0) (0)	0.02 0.08 0.03	(0) (0) (0)	0.05 0.16 0.07
Mushrooms, raw	28 100	1.0 3.5	(A.P. 1.1 oz.) 10 mushrooms, 1 $\frac{1}{2}$ " diam.	7 23	0.7 2.4	3 9	0.2 0.8	0 0	0.03 0.12	1 5	0.12 0.44
Mustard greens, raw	28 100 455	1.0 3.5 16.0	(A.P. 1.4 oz.)	6 22 100	0.7 2.3 10.5	62 220 1,001	0.8 2.9 13.2	(2,840) (10,000) (45,500)	0.03 0.09 0.41	21 75 341	0.08 0.29 1.32
Mustard greens	140	4.9	1 cup cooked	31	3.2	308	4.1	10,050	0.08	63	0.25
Nectarines, raw	28 100 167	1.0 3.5 5.9	(A.P. 1.1 oz.) 3 nectarines, 1 $\frac{3}{4}$ " diam.	17 60 100	0.1 0.5 0.8	1 4 7	0.1 0.5 0.8	426* 1,500* 2,505*	2 8 13	2 8	
* For yellow; only a trace in white.											
Noodles, egg, enriched, uncooked	28 100 26	1.0 3.5 0.9	1 $\frac{1}{8}$ cups $\frac{3}{8}$ cup, 1 $\frac{1}{2}$ " strips	108 381 100	3.6 12.6 3.3	6 22 6	0.8 2.9 0.8	57 200 52	0.25 0.88 0.23	0 0 0	0.11 0.37 0.10
Noodles, egg, enriched	126	4.4	1 cup cooked	129	2.8	5	0.6	38	0.18	(0)	0.08

Table IV (Continued). NUTRITIVE VALUES OF FOODS IN WEIGHTS

<i>Food</i>	<i>Weight</i> <i>Gm.</i>	<i>Oz.</i>	<i>Approximate Measure</i>	<i>Calo- ries</i>	<i>Pro- tein</i> <i>Gm.</i>	<i>Cal- cium</i> <i>Mg.</i>	<i>Iron</i> <i>Mg.</i>	<i>Vitamin</i> <i>A</i> <i>I.U.</i>	<i>Thia- mine</i> <i>Mg.</i>	<i>Ascorbic</i> <i>Acid</i> <i>Mg.</i>	<i>Ribo- flavin</i> <i>Mg.</i>
Noodles, egg, unenriched, uncooked	28 100 26	1.0 3.5 0.9	1½ cups ½ cup, 1½" strips	108 381 100	3.6 12.6 3.3	6 22 6	0.5 1.9 0.5	57 200 52	0.06 0.20 0.05	0 0 0	0.03 0.11 0.03
Oatmeal, rolled oats, uncooked	28 100 26	1.0 3.5 0.9	1½ cups ½ cup	111 392 100	4.0 14.2 3.7	15 53 14	1.4 5.0 1.3	(0) (0) (0)	0.17 0.61 0.16	0 0 0	0.04 0.14 0.04
Oatmeal	236	8.3	1 cup cooked	148	5.4	21	1.7	(0)	0.22	(0)	0.05
Oats, ready-to- eat cereal	28 100 25	1.0 3.5 0.9	4 cups 1 cup	113 398 100	4.1 14.5 3.6	45 160 40	1.2 4.1 1.0	(0) (0) (0)	0.22 0.79 0.20	(0) (0) (0)	0.05 0.19 0.05
Oils, salad or cooking	100 11	3.5 0.4	1 tbsp.	884 100	0 0	0 0	0 0	0* 0*	0 0	0 0	0 0
<i>* Red palm oil 13,080 I.U. vitamin A per 100 gm.</i>											
Okra, raw	28 100 313	1.0 3.5 11.0	(A.P. 1.1 oz.) 9 pods, 3" long	9 32 100	0.5 1.8 5.6	23 82 257	0.2 0.7 2.2	210 740 2,316	0.04 0.13 0.41	9 30 94	0.02 0.07 0.22
Olives, green, pickled	28 100	1.0 3.5	(A.P. 1.2 oz.) 12 olives, * 1½" × ⅞"	37 132	0.4 1.5	25 87	0.5 1.6	85 300	Trace Trace	- -	- -
<i>* Weight with pits, 114 gm.</i>											
Olives, ripe, pickled	28 100	1.0 3.5	(A.P. 1.2 oz.) 12 olives, * 1½" × ⅞"	54 191	0.5 1.8	25 87	0.5 1.6	17 60	Trace Trace	- -	Trace Trace
<i>* Weight with pits, 114 gm.</i>											
Onions, raw	28 100 222	1.0 3.5 7.8	(A.P. 1.1 oz.) ½ cup, sliced 2 onions, 2½" diam.	13 45 100	0.4 1.4 3.1	9 32 71	0.1 0.5 1.1	14 50 111	0.01 0.03 0.07	3 9 20	0.01 0.04 0.09
Onions	210	7.4	1 cup cooked	79	2.1	67	1.0	110	0.04	13	0.06
Orange juice	28 100 227 246	1.0 3.5 8.0 8.7	½ cup, scant ¾ cup 1 cup	12 33 100 108	0.2 0.8 1.8 2.0	5* 19* 43* 47*	0.1 0.3 0.7 0.7	(54)* (190)* (431)* (467)*	0.02 0.08 0.18 0.20	15 53 120 130	0.01 0.05 0.11 0.12
<i>* Fresh; canned, per 100 gm., calcium 10, vitamin A (100).</i>											

Table IV (Continued). NUTRITIVE VALUES OF FOODS IN WEIGHTS

<i>Food</i>	<i>Gm.</i>	<i>Weight Oz.</i>	<i>Approximate Measure</i>	<i>Calo- ries</i>	<i>Pro- tein Gm.</i>	<i>Cal- cium Mg.</i>	<i>Iron Mg.</i>	<i>Vitamin A I.U.</i>	<i>Thia- mine Mg.</i>	<i>Ascorbic Acid Mg.</i>	<i>Ribo- flavin Mg.</i>
Orange juice, frozen concentrate	257	9.1	1 cup reconstituted	100	1.8	23	0.7	(223)	0.16	95	0.04
Oranges	28 100 222 155	1.0 3.5 7.8 5.5	(A.P. 1.4 oz.) 2 small, 2½" diam. 1 medium, 3" diam.	13 45 100 70	0.3 0.9 2.0 1.4	9 33 73 51	0.1 0.4 0.9 0.6	64 225 500 349	0.02 0.08 0.18 0.12	15 53 118 82	0.01 0.05 0.11 0.08
Oysters, solids, raw or canned	28 100 119	1.0 3.5 4.2	¾ cup 5 medium or ½ cup	24 84 100	2.8 9.8 11.7	27 94 112	1.7 6.0 7.1	71 250 298	0.07 0.24 0.29	1 3 4	0.10 0.35 0.42
Pablum	28 100	1.0 3.5	12 tbsp. 2½ cups	105 367	4.3 15.0	221 780	8.5 30.0		0.30 1.05		0.10 0.35
Papayas, raw	28 100 256	1.0 3.5 9.0	(A.P. 1.5 oz.) ¾ cup 1¾ cups, ¾" cubes	11 39 100	0.2 0.6 1.5	6 20 51	0.1 0.3 0.8	497 1,750 4,487	0.01 0.03 0.08	21 75 192	0.01 0.04 0.10
Parsnips, raw	28 100 128	1.0 3.5 4.5	(A.P. 1.3 oz.) ½ cup, cubed 1 parsnip, 7" long	22 78 100	0.4 1.5 1.9	16 57 73	0.2 0.7 0.9	0 0 0	0.04 0.15 0.19	6 21 27	0.02 0.08 0.10
Parsnips	155	5.5	1 cup cooked	94	1.6	88	1.1	0	0.09	19	0.16
Peaches, canned in syrup	28 100 147	1.0 3.5 5.2	¾ cup 3 small halves, 3 tbsp. juice	19 68 100	0.1 0.4 0.6	1 5 7	0.1 0.4 0.6	128* 450* 662*	0.00 0.01 0.01	1 4 6	0.01 0.02 0.03
* For yellow, none in white.											
Peaches, raw	28 100 217	1.0 3.5 7.7	(A.P. 1.3 oz.) 1 medium, 2½" × 2" diam. 1½ cups, sliced	13 46 100	0.1 0.5 1.1	2 8 17	0.2 0.6 1.3	250* 880* 1,910*	0.01 0.05 0.11	2 8 17	0.01 0.05 0.11
* For yellow; white, 50 I.U. per 100 gm.											
Peanut butter	28 100 17	1.0 3.5 0.6	6 tbsp. 1 tbsp.	164 576 100	7.4 26.1 4.4	21 74 13	0.5 1.9 0.3	0 0 0	0.03 0.12 0.02	(0) (0) (0)	0.05 0.16 0.03

Table IV (Continued). NUTRITIVE VALUES OF FOODS IN WEIGHTS

<i>Food</i>	<i>Gm.</i>	<i>Weight Oz.</i>	<i>Approximate Measure</i>	<i>Calo- ries</i>	<i>Pro- tein Gm.</i>	<i>Cal- cium Mg.</i>	<i>Iron Mg.</i>	<i>Vitamin A I.U.</i>	<i>Thia- mine Mg.</i>	<i>Ascorbic Acid Mg.</i>	<i>Ribo- flavin Mg.</i>
Peanuts, roasted	28	1.0	(A.P. 1.4 oz.)	159	7.6	21	0.5	0	0.09	(0)	0.05
	100	3.5	$\frac{3}{4}$ cup, shelled	559	26.9	74	1.9	0	0.30	(0)	0.16
	18	0.6	20 kernels	100	4.8	13	0.3	0	0.05	(0)	0.03
Pears, canned in syrup	28	1.0		19	0.1	2	0.1	Trace	0.00	1	0.01
	100	3.5	$\frac{3}{8}$ cup	68	0.2	8	0.2	Trace	0.01	2	0.02
	147	5.2	3 halves, 3 tbsp. juice	100	0.3	12	0.3	Trace	0.01	3	0.03
Pears, raw	28	1.0	(A.P. 1.2 oz.)	18	0.2	4	0.1	4	0.02	1	0.03
	100	3.5		63	0.7	13	0.3	15	0.06	4	0.09
	159	5.6	1 pear, 3" long	100	1.1	21	0.5	24	0.10	6	0.14
Peas, canned, drained	28	1.0		26	1.3	9	0.6	190	0.03	3	0.02
	100	3.5	$\frac{5}{8}$ cup	91	4.5	32	2.1	670	0.12	9	0.06
	110	3.9	$\frac{3}{4}$ cup	100	5.0	35	2.3	737	0.13	10	0.07
Peas, dried, split	28	1.0		98	7.0	9	1.4	105	0.22	0	0.08
	100	3.5	$\frac{1}{2}$ cup	344	24.5	33	5.1	370	0.77	0	0.28
	29	1.0	2 tbsp.	100	7.1	10	1.5	107	0.22	0	0.08
Peas, frozen	149	5.3	1 cup uncooked	112	8.5	25	2.2	998	0.49	27	0.16
	156	5.5	1 cup cooked	150	11.4	34	2.9	1,337	0.66	36	0.21
Peas, green, raw	28	1.0	(A.P. 1.6 oz.)	28	1.9	6	0.5	270	0.11	7	0.05
	100	3.5		98	6.7	22	1.9	950	0.39	24	0.18
	102	3.6	$\frac{3}{4}$ cup	100	6.8	22	1.9	969	0.40	24	0.18
Peas, green	160	5.6	1 cup cooked	111	7.8	35	3.0	1,150	0.40	24	0.22
Pecans	28	1.0	(A.P. 1.5 oz.)	198	2.7	21	0.7	14	0.20	1	0.03
	100	3.5		696	9.4	74	2.4	50	0.72	2	0.11
	14	0.5	12 meats	100	1.3	10	0.3	7	0.10	0	0.02
Peppers, green, raw	28	1.0	(A.P. 1.2 oz.)	7	0.3	3	0.1	795	0.01	34	0.02
	100	3.5		25	1.2	11	0.4	2,800	0.05	120	0.07
	400	14.1	5 peppers, 3 $\frac{1}{2}$ " long	100	4.8	44	1.6	11,200	0.20	480	0.28
Pickles, cucum- bers, sour and dill	100	3.5		11	0.7	25	1.2	310	0.01	6	0.06
	909	32.1	7 pickles, 3 $\frac{3}{4}$ " long	100	6.4	227	10.9	2,818	0.09	55	0.55

Table IV (Continued). NUTRITIVE VALUES OF FOODS IN WEIGHTS

Food	Weight Gm.	Oz.	Approximate Measure	Calo- ries	Pro- tein Gm.	Cal- cium Mg.	Iron Mg.	Vitamin A I.U.	Thia- mine Mg.	Ascorbic Acid Mg.	Ribo- flavin Mg.
Pineapple, canned in syrup	28 100 128	1.0 3.5 4.5	$\frac{3}{4}$ cup, crushed 1 large slice, 2 tbsp. juice	22 78 100	0.1 0.4 0.5	8 29 37	0.2 0.6 0.8	23 80 102	0.02 0.07 0.09	3 9 12	0.01 0.02 0.03
Pineapple, raw	28 100 192	1.0 3.5 6.8	(A.P. 1.5 oz.) $\frac{3}{4}$ cup, $\frac{1}{2}$ " pieces 2 slices, $\frac{1}{4}$ " thick	15 52 100	0.1 0.4 0.8	5 16 31	0.1 0.3 0.6	37 130 250	0.02 0.08 0.15	7 24 46	0.01 0.05 0.10
Pineapple juice, canned	28 100 204	1.0 3.5 7.2	$\frac{3}{4}$ cup $\frac{1}{4}$ cup	14 49 100	0.1 0.3 0.6	4 15 31	0.1 0.5 1.0	23 80 163	0.01 0.05 0.10	3 9 18	0.01 0.02 0.04
Plantains (baking bananas)	28 100 84	1.0 3.5 3.0	(A.P. 1.2 oz.) 1 medium	34 119 100	0.3 1.1 0.9	2 7 6	0.2 0.7 0.6	* * *	0.02 0.06 0.05	4 14 12	0.01 0.04 0.03
* Vitamin A, 10 I.U. per 100 gm. in white to 1,200 I.U. in yellow.											
Plums, canned in syrup	28 100 132	1.0 3.5 4.7	4 plums, 1 $\frac{3}{4}$ " diam., 2 tbsp. juice	22 76 100	0.1 0.4 0.5	2 8 11	0.3 1.1 1.5	65 230 304	0.01 0.03 0.04	0 1 1	0.01 0.03 0.04
Plums, raw	28 100 200	1.0 3.5 7.1	(A.P. 1.1 oz.) 4 plums, 1 $\frac{3}{4}$ " diam.	14 50 100	0.2 0.7 1.4	5 17 34	0.1 0.5 1.0	99 350 700	0.03 0.12 0.24	2 6 12	0.01 0.04 0.08
Pork, loin chops, medium fat, raw	28 100 34	1.0 3.5 1.2	(A.P. 1.2 oz.) 1 chop	84 296 100	4.7 16.4 5.6	3 10 3	0.7 2.5 0.9	(0) (0) (0)	0.23 0.80 0.27	0 0 0	0.05 0.19 0.06
Pork, loin chops	115	4.1	1 chop cooked (with bone)	293	20.0	10	2.6	(0)	0.72	0	0.21
Pork, loin, roasted, lean only	28 100 30	1.0 3.5 1.1	Piece, 1 $\frac{3}{4}$ " \times 1" \times $\frac{3}{4}$ " 1 medium, in skin	95 333 100	6.5 23.0 6.9	3 11 3	0.9 3.0 0.9	(0) (0) (0)	0.24 0.83 0.25	0 0 0	0.07 0.24 0.07
Pork, salt, fat	100 13	3.5 0.5	Piece, 1 $\frac{3}{4}$ " \times 1" \times $\frac{3}{4}$ "	783 100	3.9 0.5	2 0	0.6 0.1	(0) (0)	(0.18) (0.02)	0 0	(0.04) (0.01)
Potato, baked	132	4.7	1 medium, in skin	100	2.5	13	0.8	21	0.11	18	0.05
Potato, boiled	128	4.5	1 medium, unpeeled	100	2.4	14	0.9	26	0.12	19	0.05
Potato chips	17	0.6	8 to 10 pieces, 2" to 3" diam.	92	1.1	(5)	(0.3)	(9)	(0.03)	2	(0.02)

Table IV (Continued). NUTRITIVE VALUES OF FOODS IN WEIGHTS

Food	Weight		Approximate Measure	Calo- ries	Pro- tein Gm.	Cal- cium Mg.	Iron Mg.	Vitamin A I.U.	Thia- mine Mg.	Ascorbic Acid Mg.	Ribo- flavin Mg.
	Gm.	Oz.									
Potato, French fried	40	1.4	8 pieces, 2" × ½" × ¼"	157	2.2	12	0.8	20	0.07	11	0.04
Potato, white, raw	28 100 120	1.0 3.5 4.2	(A.P. 1.2 oz.) 1 medium	24 83 100	0.6 2.0 2.4	3 11 13	0.2 0.7 0.8	10 35 42	0.03 0.11 0.13	5 17 20	0.01 0.04 0.05
Prune juice, canned	28 100 141	1.0 3.5 5.0	⅔ cup	20 71 100	0.1 0.4 0.6	3 10 14	0.5 1.6 2.3	— — —	0.01 0.05 0.07	1 3 4	(0.02) (0.08) (0.11)
Prunes, dried, (not sulfured)	28 100 37	1.0 3.5 1.3	(A.P. 1.2 oz.) 4 large	76 268 100	0.7 2.3 0.9	15 54 20	1.1 3.9 1.4	537 1,890 699	0.03 0.10 0.04	1 3 1	0.05 0.16 0.06
Radishes, raw	28 100	1.0 3.5	(A.P. 1.5 oz.) 10 small	6 20	0.3 1.2	11 37	0.3 1.0	9 30	0.02 0.07	5 18	0.01 0.03
Raisins, dried, (unsulfured)	28 100 37	1.0 3.5 1.3	1 cup, seeded 2½ tbsp., seedless	76 268 100	0.7 2.3 0.9	17 60 22	0.9 3.3 1.2	14 50 19	0.04 0.15 0.06	0 0 0	0.02 0.08 0.03
Raspberries, red, raw	28 100 175	1.0 3.5 6.2	(A.P. 1.0 oz.) ⅔ cup 1½ cups	16 57 100	0.3 1.2 2.1	11 40 70	0.3 0.9 1.6	37 130 228	0.01 0.02 0.04	7 24 42	0.02 0.07 0.12
Rhubarb, raw	28 100 625	1.0 3.5 22.0	(A.P. 1.3 oz.) ⅔ cup 5½ cups, 1" pieces	5 16 100	0.1 0.5 3.1	12* 44* 275*	0.1 0.5 3.1	18 65 406	0.01 0.02 0.13	5 17 106	— — —
* Availability doubtful.											
Rice, brown, uncooked	100 28	3.5 1.0	½ cup 2 tbsp.	360 100	7.5 2.1	39 11	2.0 0.6	50 14	0.32 0.09	0 0	0.05 0.01
Rice, converted, uncooked	100 28	3.5 1.0	½ cup 2 tbsp.	362 100	7.6 2.1	24 7	0.8 0.2	(0) (0)	0.20 0.06	0 0	0.03 0.01
Rice, puffed, restored	28 100 26	1.0 3.5 0.9	2 cups	111 392 100	1.7 5.9 1.5	6 21 5	0.5 1.8 0.5	(0) (0) (0)	0.13 0.46 0.12	(0) (0) (0)	0.02 0.08 0.02
Rice, white, uncooked	100 28	3.5 1.0	½ cup 2 tbsp.	362 100	7.6 2.1	9 3	0.8 0.2	(0) (0)	0.07 0.02	0 0	0.03 0.01

Table IV (Continued). NUTRITIVE VALUES OF FOODS IN WEIGHTS

Food	Weight Gm.	Oz.	Approximate Measure	Calo- ries	Pro- tein Gm.	Cal- cium Mg.	Iron Mg.	Vitamin A I.U.	Thia- mine Mg.	Ascorbic Acid Mg.	Ribo- flavin Mg.
Shrimp, canned, solids	28 100 79	1.0 3.5 2.8	20 shrimps ½ cup	36 127 100	7.6 26.8 21.2	33 115 91	0.6 2.0 1.6	17 60 47	0.00 0.01 0.01	(0) (0) (0)	0.01 0.03 0.02
Soybean curd	28 100 141	1.0 3.5 5.0	1 portion, 2½" × 2½" × 1"	20 71 100	2.0 7.0 9.9	28 100 141	0.4 1.5 2.1	— — —	0.02 0.06 0.08	0 0 0	0.01 0.05 0.07
Soybean flour, medium fat	28 100 38	1.0 3.5 1.3	¼ cup 4½ tbsp.	75 263 100	12.1 42.5 16.2	69 244 93	0.8 2.7 1.0	31 110 42	0.23 0.82 0.31	(0) (0) (0)	0.10 0.34 0.13
Soybean sprouts, raw	28 100 169	1.0 3.5 6.0	1 cup	17 59 100	1.8 6.2 10.5	14 48 81	0.3 1.0 1.7	51 180 304	0.07 0.23 0.39	4 13 22	0.06 0.20 0.34
Soybeans, dried	28 100 30	1.0 3.5 1.1	½ cup 2 tbsp.	93 329 100	9.9 34.9 10.5	64 227 68	2.3 8.0 2.4	31 110 33	0.30 1.07 0.32	Trace Trace Trace	0.09 0.31 0.09
Spaghetti, enriched, uncooked	28 100 26	1.0 3.5 0.9	1 cup, 2" pieces	107 377 100	3.6 12.8 3.3	6 22 6	0.8 2.9 0.8	(0) (0) (0)	0.25 0.88 0.23	(0) (0) (0)	0.11 0.37 0.10
Spaghetti, enriched	146	5.1	1 cup cooked	218	7.4	13	1.6	(0)	0.25	(0)	0.15
Spinach, raw	28 100 500	1.0 3.5 17.6	(A.P. 1.2 oz.) 3 quarts	6 20 100	0.7 2.3 11.5	23* 81* 405*	0.9 3.0 15.0	(2,840) (10,000) (50,000)	0.03 0.11 0.55	11 38 190	0.07 0.26 1.30
* May not be available because of oxalic acid present.											
Spinach	180	6.3	1 cup cooked	46	5.6	223*	3.6	21,200	0.14	54	0.36
* May not be available because of oxalic acid present.											
Squash, summer, raw	28 100 625	1.0 3.5 22.0	(A.P. 1.03 oz.) ¾ squash, 5" diam.	5 16 100	0.2 0.6 3.8	4 15 94	0.1 0.4 2.5	85 300 1,875	0.01 0.04 0.25	4 15 94	0.02 0.07 0.44
Squash, summer	210	7.4	1 cup cooked	34	1.3	32	0.8	550	0.08	23	0.15
Squash, winter (Hubbard), raw	28 100 263	1.0 3.5 9.3	(A.P. 1.3 oz.) 1 piece, 2" × 4" × 1½"	11 38 100	0.4 1.5 3.9	5 19 50	0.2 0.6 1.6	994 3,500 9,205	0.01 0.05 0.13	1 5 13	0.02 0.08 0.21
Squash, winter	229	8.1	1 cup cooked	86	3.4	43	1.4	11,290	0.09	11	0.23

Table IV (Continued). NUTRITIVE VALUES OF FOODS IN WEIGHTS

Food	Weight		Approximate Measure	Calo- ries	Pro- tein Gm.	Cal- cium Mg.	Iron Mg.	Vitamin A I.U.	Thia- mine Mg.	Ascorbic Acid Mg.	Ribo- flavin Mg.
	Gm.	Oz.									
Starch, pure (corn, arrowroot, etc.)	100 28	3.5 1.0	$\frac{1}{2}$ cup 3 tbsp.	362 100	0.5 0.1	(0) (0)	(0) (0)	(0) (0)	(0) (0)	(0) (0)	(0) (0)
Strawberries, raw	28 100 270	1.0 3.5 9.5	(A.P. 1.04 oz.) $\frac{1}{2}$ cup 1 $\frac{3}{4}$ cups	11 37 100	0.2 0.8 2.2	8 28 76	0.2 0.8 2.2	21 75 203	0.01 0.03 0.08	13 47 127	0.01 0.05 0.14
Sugar, brown	100 27	3.5 1.0	$\frac{1}{2}$ cup 3 tbsp.	370 100	(0) (0)	76* 21*	2.6 0.7	(0) (0)	(0) (0)	(0) (0)	(0) (0)
* For dark brown; lower values for light.											
Sugar, granu- lated	100 26	3.5 0.9	$\frac{1}{2}$ cup 2 tbsp.	385 100	(0) (0)	0 0	0 0	0 0	0 0	0 0	0 0
Sugar, maple	100 29	3.5 1.0	1 piece, 1 $\frac{3}{4}$ " \times 1 $\frac{1}{4}$ " \times $\frac{1}{2}$ "	348 100	0 0	— —	— —	0 0	0 0	0 0	0 0
Sweetbreads, beef, medium fat, raw	28 100 29	1.0 3.5 1.0	$\frac{3}{4}$ cup	98 344 100	3.4 11.8 3.4	4 14 4	0.5 1.6 0.5		0.04 0.15 0.04		0.16 0.55 0.16
Sweet potatoes	28 100 81	1.0 3.5 2.9	(A.P. 1.1 oz.) $\frac{1}{2}$ medium	35 123 100	0.5 1.8 1.5	9 30 24	0.2 0.7 0.6	2,187* 7,700* 6,237*	0.03 0.11 0.09	5 19 15	0.02 0.08 0.06
* For yellow varieties.											
Swordfish	(see Fish)										
Syrup, table blends	100 35	3.5 1.2	5 tbsp.	286 100	(0) (0)	46 16	4.1 1.4	0 0	0 0	(0) (0)	0.01 0.00
Syrup, maple	100 36	3.5 1.3	5 tbsp.	276 100	0 0	163 59	3.0 1.1	0 0	0 0	0 0	0 0
Tangerines	28 100 227	1.0 3.5 8.0	(A.P. 1.3 oz.) 3 medium, 2 $\frac{1}{2}$ " diam.	12 44 100	0.2 0.8 1.8	(9) (33) (75)	0.1 0.5 1.1	(119) (420) (953)	0.02 0.07 0.16	9 31 70	0.01 0.03 0.07
Tapioca (cassava, manioc, yuca)	100 28	3.5 1.0	$\frac{1}{2}$ cup uncooked 2 tbsp. uncooked	360 100	0.6 0.2	12 3	(1.0) (0.3)	(0) (0)	0 0	0 0	(0) (0)

Table IV (Continued). NUTRITIVE VALUES OF FOODS IN WEIGHTS

<i>Food</i>	<i>Weight</i> <i>Gm.</i> (see Yautia)	<i>Oz.</i>	<i>Approximate Measure</i>	<i>Calo- ries</i>	<i>Pro- tein</i> <i>Gm.</i>	<i>Cal- cium</i> <i>Mg.</i>	<i>Iron</i> <i>Mg.</i>	<i>Vitamin</i> <i>A</i> <i>I.U.</i>	<i>Thia- mine</i> <i>Mg.</i>	<i>Ascorbic</i> <i>Acid</i> <i>Mg.</i>	<i>Ribo- flavin</i> <i>Mg.</i>
Taro											
Tomato juice, canned	28 100 476	1.0 3.5 16.8	2 cups	6 21 100	0.3 1.0 4.8	2 7 33	(0.1) (0.4) (1.9)	298 1,050 4,998	0.01 0.05 0.24	5 16 76	0.01 0.03 0.14
Tomatoes, canned	28 100 526	1.0 3.5 18.6	2½ cups	5 19 100	0.3 1.0 5.3	2 6 32	0.1 0.5 2.6	298 1,050 5,523	0.02 0.06 0.32	5 16 84	0.01 0.03 0.16
Tomatoes, raw	28 100 500	1.0 3.5 17.6	(A.P. 1.1 oz.) 1 small 3 tomatoes, 2½" diam.	6 20 100	0.3 1.0 5.0	3 11 55	0.2 0.6 3.0	312 1,100 5,500	0.02 0.06 0.30	7 23 115	0.01 0.04 0.20
Tuna			(see Fish)								
Turkey, medium fat, raw	28 100 37	1.0 3.5 1.3	(A.P. 1.3 oz.) 1 slice, 3" × 2½" × ¼"	76 268 100	5.7 20.1 7.4	7 23 9	1.1 3.8 1.4	Trace Trace Trace	0.03 0.09 0.03	(0) (0) (0)	0.04 0.14 0.05
Turnip greens, raw	28 100 333	1.0 3.5 11.7	(A.P. 1.2 oz.)	9 30 100	0.8 2.9 9.7	74 260 866	0.7 2.4 8.0	(2,840) (10,000) (33,300)	0.04 0.14 0.47	39 136 453	0.13 0.46 1.53
Turnip greens	145	5.1	1 cup cooked	43	4.2	376	3.5	15,370	0.09	87	0.59
Turnips, white, raw	28 100 313	1.0 3.5 11.0	(A.P. 1.1 oz.) 4 turnips, 2" diam.	9 32 100	0.3 1.1 3.4	11 40 125	0.1 0.5 1.6	5 15 47	0.01 0.05 0.16	8 28 88	0.02 0.07 0.22
Turnips	155	5.5	1 cup cooked	42	1.2	62	0.8	Trace	0.06	28	0.09
Turnips, yellow			(see Rutabagas)								
Veal, leg, lean, raw	28 100 64	1.0 3.5 2.3	(A.P. 1.2 oz.) 1 slice, 2" × 2¾" × ¼"	44 156 100	5.6 19.7 12.6	3 11 7	0.9 3.0 1.9	(0) (0) (0)	0.04 0.14 0.09	0 0 0	0.07 0.26 0.17
Veal cutlet, raw, medium fat	28 100 61	1.0 3.5 2.2		47 164 100	5.5 19.5 11.9	3 11 7	0.8 2.9 1.8	(0) (0) (0)	0.04 0.14 0.09	0 0 0	0.07 0.26 0.16
Walnuts, English	28 100 15	1.0 3.5 0.5	(A.P. 1.6 oz.) 1 cup, halves 8 to 16 meats	186 654 100	4.3 15.0 2.3	24 83 12	0.6 2.1 0.3	9 30 5	0.14 0.48 0.07	1 3 0	0.04 0.13 0.02

Table IV (Continued). NUTRITIVE VALUES OF FOODS IN WEIGHTS

<i>Food</i>	<i>Weight</i> <i>Gm.</i>	<i>Öz.</i>	<i>Approximate Measure</i>	<i>Calo- ries</i>	<i>Pro- tein</i> <i>Gm.</i>	<i>Cal- cium</i> <i>Mg.</i>	<i>Iron</i> <i>Mg.</i>	<i>Vitamin</i> <i>A</i> <i>I.U.</i>	<i>Thia- mine</i> <i>Mg.</i>	<i>Ascorbic</i> <i>Acid</i> <i>Mg.</i>	<i>Ribo- flavin</i> <i>Mg.</i>
Watermelon	28	1.0	(A.P. 1.5 oz.)	8	0.1	2	0.1	91	0.01	2	0.01
	100	3.5		28	0.5	7	0.2	320	0.04	6	0.04
	357	12.6	1 slice, $\frac{3}{4}$ " thick, 6" diam.	100	1.8	25	0.7	1,142	0.14	21	0.14
Wheat flakes (Pep, Wheaties, etc.), enriched	100	3.5		355	10.8	46	4.2	(0)	0.56	0	0.18
	28	1.0	$\frac{8}{5}$ cup	100	3.0	13	1.2	(0)	0.16	0	0.05
Wheat germ	100	3.5	1 $\frac{1}{2}$ cups	361	25.2	84	8.1	(0)	2.05	(0)	0.80
	28	1.0		100	7.1	24	2.3	(0)	0.57	(0)	0.22
	28	1.0		98	3.6	13	1.1	(0)	0.16	0	0.04
	100	3.5		344	12.7	46	3.8	(0)	0.55	0	0.15
(Wheatena, etc.)	29	1.0	$\frac{1}{3}$ cup uncooked	100	3.7	13	1.1	(0)	0.16	0	0.04
	243	5.0	1 cup cooked	175	6.6	22	1.7	(0)	0.25	0	0.08
Wheat, puffed, restored	100	3.5		355	10.8	46	4.2	0	0.56	0	0.18
	28	1.0	2 $\frac{3}{8}$ cups	100	3.0	13	1.2	0	0.16	0	0.05
Wheat, shredded	100	3.5		360	10.1	47	3.5	0	0.22	0	0.12
	28	1.0	1 large biscuit	100	2.8	13	1.0	0	0.06	0	0.03
Yams, white, raw	28	1.0	(A.P. 1.1 oz.)	29	0.6	6	0.2	Trace	0.03	3	0.01
	100	3.5		101	2.1	20	0.6	Trace	0.10	9	0.04
	99	3.5		100	2.1	20	0.6	Trace	0.10	9	0.04
Yautia, white (taro, dasheen, tania, etc.)	28	1.0	(A.P. 1.2 oz.)	26	0.6	7	0.3	6	0.04	1	0.01
	100	3.5		90	2.0	25	1.0	20	0.13	4	0.04
	111	3.9	$\frac{1}{2}$ yautia, 4" long	100	2.2	28	1.1	22	0.14	4	0.04
Yeast, dried (brewer's)	28	1.0		71	(10.5)	30	5.2	(0)	2.75	(0)	1.55
	100	3.5		249	(36.9)	106	18.2	(0)	9.69	(0)	5.45
	40	1.4	5 tbsp.	100	(14.8)	42	7.3	(0)	3.88	(0)	2.18

NOTE ON TABLES V, VI, VII, VIII, IX, X, AND XI

Tables V and VI which appear in the following pages give weight and height ranges of American children at different ages from birth to five years. Table V has been taken from *Infant Care*, Children's Bureau Publication No. 8 (1940). Table VI was prepared by Dr. Robert M. Woodbury; and Table VII from *Basic Body Measurements of School Age Children*, Office of Education, U. S. Department of Health, Education, and Welfare (1953). It must be remembered that these figures are averages of large numbers of children. No child is expected to conform to the exact weight for height and age indicated in these tables. Differences in type of build, in speed

of development, and many other factors make such arbitrary use impossible. At the same time these tables are valuable in showing the trend of growth in weight and height from year to year. Each child grows at his own rate and the important thing is that the gain is steady.

Tables VIII and IX are from *Personal Health Standard and Scale* by Thomas D. Wood, M.D., Bureau of Publications, Teachers College, Columbia University. Tables X and XI are from *What Is Your Weight?*, Metropolitan Life Insurance Company (1954).

Table V. WEIGHT—HEIGHT—AGE TABLES^a FOR INFANTS
Weight-Height-Age Table for White Boys from Birth to 1 Year (without Clothes)

		Average Weight in Pounds for Each Month of Age										
Height in Inches	Less than 1 Month	1 Month	2 Months	3 Months	4 Months	5 Months	6 Months	7 Months	8 Months	9 Months	10 Months	11 Months
		but Less than 2	but Less than 3	but Less than 4	but Less than 5	but Less than 6	but Less than 7	but Less than 8	but Less than 9	but Less than 10	but Less than 11	but Less than 12
17	5½	..	..	..	..	..	..	..	..	..	..	..
18	6½	..	..	..	..	..	..	..	..	..	..	..
19	7½	7½	..	..	..	..	..	..	..	..	..	..
20	8	8½	9	..	..	..	..	..	..	..	..	..
21	9	9½	10	10½	10½	..	..	..	..	..	..	..
22	10	10½	11	11½	11½	12	..	..	..	..	..	..
23	10½	11½	12	12½	13	13	13½	..	..	..	..	..
24	11½	12½	13	13½	14	14½	14½	14½	14	..	..	..
25	12½	13½	14	14½	15	15½	15½	15½	15	15	15	..
26	..	14	15	15½	16	16½	16½	17	16	16	16	16½
27	..	..	16	16½	17	17½	18	18	17	17	17½	18
28	..	..	..	17½	18	19	19	19	18½	18½	18½	19
29	..	..	..	..	19½	20	20½	20½	19½	19½	19½	20
30	..	..	..	..	21½	21½	21½	21½	20½	20½	20½	21
31	..	..	..	..	..	22½	23	23	21½	21½	22	22
32	..	..	..	..	..	..	24	24	23	23	23	23
33	..	..	..	..	..	..	..	..	24	24	24	24
									..	..	25	25

Table V (Continued). WEIGHT—HEIGHT—AGE TABLES^a FOR INFANTS
Weight-Height-Age Table for White Girls from Birth to 1 Year (without Clothes)

<i>Average Weight in Pounds for Each Month of Age</i>													
<i>Height in Inches</i>	<i>1 Month Less than 1 Month</i>	<i>2 Months but Less than 2</i>	<i>3 Months but Less than 3</i>	<i>4 Months but Less than 4</i>	<i>5 Months but Less than 5</i>	<i>6 Months but Less than 6</i>	<i>7 Months but Less than 7</i>	<i>8 Months but Less than 8</i>	<i>9 Months but Less than 9</i>	<i>10 Months but Less than 10</i>	<i>11 Months but Less than 11</i>	<i>11 Months but Less than 12</i>	
17	5½	..	..	..	..	..	..	..	..	..	..	..	..
18	6½	..	..	..	..	..	..	..	..	..	..	..	..
19	7½	8	..	..	..	..	..	..	..	..	..	..	..
20	8	9	9	..	..	..	..	..	..	..	..	..	..
21	8½	9½	10	10½	11	..	..	..	..	..	..	..	..
22	9½	10	11	11½	12	12	12	12½	..	..	..	..	..
23	10	11	12	12½	13	13	13	13½	13½	13½	..	..	..
24	11	12	13	13½	14	14	14	14½	14½	14½	13½	14½	14½
25	11½	13	14	14½	15	15	15½	15½	15½	15½	16	16	16
26	..	14	15	15½	16	16	16½	16½	16½	16½	17	17	17
27	..	..	16	16½	17	17	17½	17½	17½	17½	18	18	18
28	..	..	17	17½	18	18	18½	18½	19	19	19	19	19
29	..	..	..	19	19	19½	20	20	20	20	20	20	20
30	..	..	..	..	20	20½	21	21	21	21	21	21	21
31	..	..	..	..	..	21½	22	22	22	22	22½	22½	22½
32	..	..	..	..	..	..	..	23	23	23½	23½	23½	23½
33	..	..	..	..	..	..	..	..	..	..	..	..	24½

^a Reanalysis of the weight, height, and age of 20,299 white boys and of 19,493 white girls under 12 months of age, examined in Children's Year (1918-19). The number of Negro boys and girls measured and weighed was not sufficiently large to provide comparable data.

Table VI. WEIGHT—HEIGHT—AGE TABLES FOR CHILDREN

From One Year to School Age

Boys										Girls														
Average Weight for Height (Pounds)					Height (Inches)					Average Weight for Height (Pounds)					Height (Inches)									
26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	12 Mos.	18 Mos.	24 Mos.	30 Mos.	36 Mos.	48 Mos.	
16½	18	19½	20½	22	23	24½	26	27	29½	31	32	33½	35	36½	38	39½	41½	17	18	19	20	21	22	23
22	23	24½	26	27	29	31	33	34	35	36	37	38	39	40	41	42	43	21	21	21	21	21	21	21
22	23	24½	26	27	29	31	33	34	35	36	37	38	39	40	41	42	43	22	23	23	23	23	23	23
24½	26	27	29	31	33	34	35	36	37	38	39	40	41	42	43	44	45	23	24	24	24	24	24	24
26	27	29	31	33	34	35	36	37	38	39	40	41	42	43	44	45	46	25	25	25	25	25	25	25
27	29	31	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	26	26	26	26	26	26	26
29½	31	32	33½	35	36½	38	39½	41½	43	44½	46½	48½	50½	52½	54½	56½	58½	29	29	29	29	29	29	29
31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	30	30	30	30	30	30	30
32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	31	31	31	31	31	31	31
33½	35	36½	38	39½	41½	43	44½	46½	48½	50½	52½	54½	56½	58½	60½	62½	64½	32	32	32	32	32	32	32
35	36½	38	39½	41½	43	44½	46½	48½	50½	52½	54½	56½	58½	60½	62½	64½	66½	33	33	33	33	33	33	33
36½	38	39½	41½	43	44½	46½	48½	50½	52½	54½	56½	58½	60½	62½	64½	66½	68½	34	34	34	34	34	34	34
40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	35	35	35	35	35	35	35
41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	36	36	36	36	36	36	36
42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	37	37	37	37	37	37	37
43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	38	38	38	38	38	38	38
44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	39	39	39	39	39	39	39
45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	40	40	40	40	40	40	40
46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	41	41	41	41	41	41	41
47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	42	42	42	42	42	42	42
48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	43	43	43	43	43	43	43
49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	44	44	44	44	44	44	44
50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	45	45	45	45	45	45	45
51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	46	46	46	46	46	46	46
52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	47	47	47	47	47	47	47
53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	48	48	48	48	48	48	48
54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	49	49	49	49	49	49	49
55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	50	50	50	50	50	50	50
56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	51	51	51	51	51	51	51
57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	52	52	52	52	52	52	52
58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	53	53	53	53	53	53	53
59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	54	54	54	54	54	54	54
60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	55	55	55	55	55	55	55
61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	56	56	56	56	56	56	56
62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	57	57	57	57	57	57	57
63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	58	58	58	58	58	58	58
64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	59	59	59	59	59	59	59
65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	60	60	60	60	60	60	60
66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	61	61	61	61	61	61	61
67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	62	62	62	62	62	62	62
68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	63	63	63	63	63	63	63
69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	64	64	64	64	64	64	64
70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	65	65	65	65	65	65	65
71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	66	66	66	66	66	66	66
72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	67	67	67	67	67	67	67
73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	68	68	68	68	68	68	68
74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	69	69	69	69	69	69	69
75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	70	70	70	70	70	70	70
76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	71	71	71	71	71	71	71
77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	72	72	72	72	72	72	72
78	79	80	81	82	83	84	85	86	87	88	89	90												

Table VII. WEIGHT—HEIGHT—AGE TABLE FOR BOYS AND GIRLS OF SCHOOL AGE ^a

<i>Boys</i>						<i>Girls</i>			
<i>Age Years</i>	<i>Average Weight Pounds</i>	<i>Range ^b in Weight Pounds</i>	<i>Average Height Inches</i>	<i>Range ^b in Height Inches</i>	<i>Age Years</i>	<i>Average Weight Pounds</i>	<i>Range ^b in Weight Pounds</i>	<i>Average Height Inches</i>	<i>Range ^b in Height Inches</i>
4	38.2	33.7—42.7	40.9	39.0—42.8	4	37.3	32.5—42.1	40.9	39.0—42.8
5	43.2	37.7—48.7	43.9	41.9—45.9	5	42.0	36.1—47.9	43.6	41.6—45.6
6	47.6	41.3—53.9	46.1	44.0—48.2	6	46.4	39.6—53.2	45.8	43.7—47.9
7	52.5	45.4—59.6	48.2	46.0—50.4	7	51.2	43.7—58.7	47.9	45.7—50.1
8	58.2	49.5—66.9	50.4	48.1—52.7	8	56.9	47.5—66.3	50.0	47.7—52.3
9	64.4	54.6—74.2	52.4	50.0—54.8	9	63.0	51.9—74.1	52.0	49.6—54.4
10	70.7	59.2—82.2	54.3	51.8—56.8	10	70.3	57.1—83.5	54.2	51.6—56.8
11	77.6	64.5—90.7	56.2	53.6—58.8	11	79.0	63.5—94.5	56.5	53.7—59.3
12	85.6	69.8—101.4	58.2	55.3—61.1	12	89.7	71.9—107.5	59.0	56.1—61.9
13	95.6	77.4—113.8	60.5	57.3—63.7	13	100.3	82.3—118.3	60.6	58.0—63.2
14	107.9	87.8—128.0	63.0	59.6—66.4	14	108.5	91.3—125.7	62.3	59.9—64.7
15	121.7	101.1—142.3	65.6	62.5—68.7	15	115.0	98.8—131.2	63.2	60.9—65.5
16	131.9	113.0—150.8	67.3	64.5—70.1	16	117.6	101.7—133.5	63.5	61.3—65.7
17	138.3	119.5—157.1	68.2	65.6—70.8	17	119.0	103.5—134.5	63.6	61.4—65.8

^aFrom "Basic Body Measurements of School Age Children," Office of Education, U. S. Department of Health, Education, and Welfare, 1953. This table is a compilation of heights and weights of 296,498 children (152,191 boys and 144,307 girls) from 17 states and the District of Columbia. No data reported before 1930 were included. The measurements were made on subjects wearing light indoor clothing with shoes removed.

^bThe ranges given include the cases which fell within the middle two-thirds of those in the sample.

Table VIII. TABLE OF WEIGHT AND HEIGHT FOR MEN
AT DIFFERENT AGES ^a

In ascertaining height—measure yourself in shoes; stand erect, and press measuring rod down against scalp. Weigh yourself in indoor clothing and shoes. Subtract for height of heel. Weights are given in pounds.

Height	Age in Years											
	18	19	20	21- 22	23- 24	25- 29	30- 34	35- 39	40- 44	45- 49	50- 54	55- 59
5 ft.	..	111	112	114	118	122	126	128	131	133	134	135
5 ft. 1 in.	..	116	117	118	121	124	128	130	133	135	136	137
5 ft. 2 in.	..	122	123	124	125	126	130	132	135	137	138	139
5 ft. 3 in.	123	127	128	128	129	131	133	135	138	140	141	142
5 ft. 4 in.	126	130	131	132	134	135	136	138	141	143	144	145
5 ft. 5 in.	131	134	135	136	137	138	140	142	145	147	148	149
5 ft. 6 in.	136	139	140	141	142	143	144	146	149	151	152	153
5 ft. 7 in.	139	142	143	144	145	146	148	150	153	155	156	158
5 ft. 8 in.	143	147	148	149	150	151	152	155	158	160	161	163
5 ft. 9 in.	149	152	153	154	155	156	158	160	163	165	166	168
5 ft. 10 in.	151	155	156	157	158	159	162	165	168	170	171	173
5 ft. 11 in.	154	159	160	161	162	164	166	170	174	176	177	178
6 ft.	158	163	164	165	166	168	172	176	180	182	183	184
6 ft. 1 in.	164	167	168	169	171	173	178	182	186	188	190	191
6 ft. 2 in.	170	171	172	174	176	179	184	189	193	195	197	198
6 ft. 3 in.	..	175	175	178	181	184	190	195	200	202	204	205
6 ft. 4 in.	..	178	180	183	186	189	196	201	206	209	211	212
6 ft. 5 in.	..	183	185	188	191	194	201	207	212	215	217	219

Table IX. TABLE OF WEIGHT AND HEIGHT FOR WOMEN
AT DIFFERENT AGES ^b

In ascertaining height—measure yourself in shoes; stand erect, and press measuring rod down against scalp. Weigh yourself in indoor clothing and shoes. Subtract for height of heel. Weights are given in pounds.

Height	Age in Years										
	18	19	20	21- 22	23- 24	25- 29	30- 34	35- 39	40- 44	45- 49	50- 54
4 ft. 10 in.	..	104	106	108	110	113	116	119	123	126	129
4 ft. 11 in.	..	106	107	109	112	115	118	121	125	128	131
5 ft.	..	112	112	113	115	117	120	123	127	130	133
5 ft. 1 in.	116	116	116	116	118	119	122	125	129	132	135
5 ft. 2 in.	118	118	118	119	120	121	124	127	132	135	138
5 ft. 3 in.	120	120	121	122	123	124	127	130	135	138	141
5 ft. 4 in.	123	123	124	125	126	128	131	134	138	141	144
5 ft. 5 in.	126	126	127	128	129	131	134	138	142	145	148
5 ft. 6 in.	130	130	131	132	133	135	138	142	146	149	152
5 ft. 7 in.	135	135	135	135	137	139	142	146	150	153	156
5 ft. 8 in.	138	138	138	139	141	143	146	150	154	157	161
5 ft. 9 in.	..	142	142	142	145	147	150	154	158	161	165
5 ft. 10 in.	..	144	144	145	148	151	154	157	161	164	169
5 ft. 11 in.	..	146	147	149	151	154	157	160	164	168	173
6 ft.	..	150	152	154	156	158	161	163	167	171	176

^a From *Personal Health Standard and Scale*, by Thomas D. Wood, M.D., Bureau of Publications, Teachers College, Columbia University.

^b *Ibid.*

Table X. DESIRABLE WEIGHTS FOR MEN^a
AGE 25 OR OVER

<i>Height</i> (with shoes on)*		<i>Weight in Pounds According to Frame</i> (as Ordinarily Dressed)		
<i>Feet</i>	<i>Inches</i>	<i>Small Frame</i>	<i>Medium Frame</i>	<i>Large Frame</i>
5	2	116-125	124-133	131-142
5	3	119-128	127-136	133-144
5	4	122-132	130-140	137-149
5	5	126-136	134-144	141-153
5	6	129-139	137-147	145-157
5	7	133-143	141-151	149-162
5	8	136-147	145-156	153-166
5	9	140-151	149-160	157-170
5	10	144-155	153-164	161-175
5	11	148-159	157-168	165-180
6	0	152-164	161-173	169-185
6	1	157-169	166-178	174-190
6	2	163-175	171-184	179-196
6	3	168-180	176-189	184-202

* Subtract height of heel.

Table XI. DESIRABLE WEIGHTS FOR WOMEN^a
AGE 25 OR OVER*

<i>Height</i> (with shoes on)**		<i>Weight in Pounds According to Frame</i> (as Ordinarily Dressed)		
<i>Feet</i>	<i>Inches</i>	<i>Small Frame</i>	<i>Medium Frame</i>	<i>Large Frame</i>
4	11	104-111	110-118	117-127
5	0	105-113	112-120	119-129
5	1	107-115	114-122	121-131
5	2	110-118	117-125	124-135
5	3	113-121	120-128	127-138
5	4	116-125	124-132	131-142
5	5	119-128	127-135	133-145
5	6	123-132	130-140	138-150
5	7	126-136	134-144	142-154
5	8	129-139	137-147	145-158
5	9	133-143	141-151	149-162
5	10	136-147	145-155	152-166
5	11	139-150	148-158	155-169

* For girls between 18 and 25, subtract 1 pound for each year under 25.

** Subtract height of heel.

^a From "What is Your Weight?" Metropolitan Life Insurance Company (1954).

**Table XII. MASTER FOOD PLAN AT MODERATE COST. WEEKLY QUANTITIES OF FOOD (AS PURCHASED)
FOR 19 AGE, SEX, AND ACTIVITY GROUPS^a**

<i>Family Members</i>	<i>Leafy, Green, and Yellow Vegetables</i>	<i>Citrus Fruit, Tomatoes</i>	<i>Potatoes, Sweet Potatoes</i>	<i>Other Vege- tables and Fruit</i>	<i>Milk^b</i>	<i>Meat, Poultry, Fish</i>	<i>Eggs</i>	<i>Dry Beans and Peas, Nuts</i>	<i>Flour, Cereals^c</i>	<i>Fats and Oils^d</i>	<i>Sugar, Syrups, Pre- serves</i>
Children through 12 years:											
9-12 months	Lb. Oz. 1—8	Lb. Oz. 1—12	Lb. Oz. 0—8	Lb. Oz. 1—0	Qt. 6	Lb. Oz. 0—4	No. 5	Lb. Oz. 0—1	Lb. Oz. 0—10	Lb. Oz. 0—1	Lb. Oz. 0—1
1-3 years	2—0	2—0	0—8	1—12	6	0—12 ^e	6	0—1	1—4	0—2	0—2
4-6 years	2—4	2—4	1—0	2—4	6	1—4	7	0—1	1—8	0—6	0—8
7-9 years	2—8	2—8	1—12	2—8	6½	1—12	7	0—2	2—0	0—8	0—12
10-12 years	3—0	2—12	2—4	2—8	7	2—4	7	0—2	2—12	0—12	0—14
Girls:											
13-15 years	3—8	2—12	2—8	3—8	7	2—12 ^e	7	0—2	2—12	0—14	0—14
16-20 years	3—8	2—12	2—8	3—8	6	2—12 ^e	7	0—2	2—8	0—12	0—14
Boys:											
13-15 years	3—8	3—0	3—8	3—8	7	3—0	7	0—4	4—0	1—2	1—2
16-20 years	4—0	3—8	4—8	3—8	7	3—4	7	0—6	5—4	1—6	1—4
Women:											
Sedentary	3—4	2—8	1—12	3—4	5	2—8	7	0—1	1—12	0—10	0—12
Moderately active	3—8	2—8	2—8	3—8	5	2—12	7	0—2	2—8	0—14	0—14
Very active	3—12	3—0	3—4	4—0	5	3—0	7	0—4	3—12	1—2	1—2
Pregnant	4—0	3—8	2—4	3—0	7½	3—0 ^e	7	0—2	2—4	0—10	0—10
Nursing	4—0	4—8	3—0	3—8	10½	3—0 ^e	7	0—2	2—8	0—12	0—12
60 years or over	3—8	2—12	2—0	3—0	5½	2—8	6	0—1	1—12	0—8	0—10
Men:											
Sedentary	3—8	2—8	2—8	3—8	5	2—12	7	0—2	2—8	0—14	0—14
Physically active	3—12	3—0	3—4	4—0	5	3—0	7	0—4	3—12	1—2	1—2
With heavy work	4—0	3—8	5—0	4—4	5	3—8	7	0—6	7—0	2—0	1—4
60 years or over	3—8	2—12	2—12	3—0	5½	2—12	6	0—2	2—8	0—12	0—12

^a From *Helping Families Plan Food Budgets*. Miscellaneous Publication No. 662, U. S. Department of Agriculture, Agricultural Research Administration, October 1952.

^b Or its equivalent in cheese, evaporated milk, or dry milk.

^c Count 1½ pounds of bread as 1 pound of flour. Use as much as possible in the form of whole-grain, enriched, or restored products.

^d For small children and pregnant and nursing women, cod liver oil or some other source of vitamin D is also needed. For elderly persons and for persons who have no opportunity for exposure to clear sunshine, a small amount of vitamin D is also desirable.

^e To meet iron allowance, 1 large or 2 small servings of liver or other organ meats should be served each week.

**Table XIII. MASTER FOOD PLAN AT LOW COST. WEEKLY QUANTITIES OF FOOD (AS PURCHASED)
FOR 19 AGE, SEX, AND ACTIVITY GROUPS^a**

<i>Family Members</i>	<i>Leafy, Green, and Yellow Vegetables</i>	<i>Citrus Fruit, Tomatoes</i>	<i>Potatoes, Sweet Potatoes</i>	<i>Other Vege- tables and Fruit</i>	<i>Milk^b</i>	<i>Meat, Poultry, Fish</i>	<i>Eggs</i>	<i>Dry Beans and Peas, Nuts</i>	<i>Flour, Cereals^c</i>	<i>Fats and Oils^d</i>	<i>Sugar, Syrups, Pre- serves</i>
Children through 12 years:											
9-12 months	Lb. Oz. 1—8	Lb. Oz. 1—12	Lb. Oz. 0—8	Lb. Oz. 1—0	Qt. 6	Lb. Oz. 0—4	No. 5	Lb. Oz. 0—1	Lb. Oz. 0—10	Lb. Oz. 0—1	Lb. Oz. 0—1
1-3 years	1—12	1—12	1—0	1—0	5½	0—8 ^e	5	0—1	1—4	0—2	0—2
4-6 years	1—12	1—12	1—8	1—4	5½	1—0	5	0—2	1—12	0—6	0—6
7-9 years	2—0	2—0	2—8	1—8	5½	1—8	5	0—4	2—4	0—8	0—10
10-12 years	2—4	2—4	3—0	1—12	6	1—12	5	0—4	3—4	0—12	0—12
Girls:											
13-15 years	2—4	2—4	3—4	1—12	6½	2—0 ^e	5	0—4	3—8	0—12	0—12
16-20 years	2—4	2—4	3—0	1—12	5	2—0 ^e	5	0—4	3—4	0—12	0—10
Boys:											
13-15 years	2—8	2—8	4—0	2—4	6½	2—0	5	0—8	4—8	1—0	0—14
16-20 years	2—12	2—8	5—0	2—8	6½	2—0	5	0—8	5—12	1—6	1—0
Women:											
Sedentary	2—4	2—0	2—4	1—12	5	2—0	5	0—4	2—0	0—10	0—10
Moderately active	2—4	2—0	3—0	1—12	5	2—0	5	0—4	3—4	0—12	0—12
Very active	2—8	2—8	4—0	2—0	5	2—0	5	0—6	4—4	1—0	1—0
Pregnant	3—0	2—8	2—8	2—0	7½	2—4 ^e	7	0—4	2—8	0—10	0—8
Nursing	3—8	3—12	4—0	2—4	10½	2—8 ^e	7	0—4	3—0	0—10	0—8
60 years or over	2—8	2—4	2—8	1—12	5	2—0	4	0—2	2—4	0—8	0—8
Men:											
Sedentary	2—4	2—0	3—0	1—12	5	2—0	5	0—4	3—4	0—12	0—12
Physically active	2—8	2—8	4—0	2—0	5	2—0	5	0—6	4—4	1—0	1—0
With heavy work	2—8	2—8	6—0	2—8	5	2—0	5	0—10	7—12	1—14	1—0
60 years or over	2—8	2—4	3—4	1—12	5	2—0	4	0—2	3—4	0—10	0—10

^aFrom *Helping Families Plan Food Budgets*. Miscellaneous Publication No. 662, U. S. Department of Agriculture, Agricultural Research Administration, October 1952.

^bOr its equivalent in cheese, evaporated milk, or dry milk.

^cCount 1½ pounds of bread as 1 pound of flour. Use as much as possible in the form of whole-grain, enriched, or restored products.

^dFor small children and pregnant and nursing women, cod liver oil or some other source of vitamin D is also needed. For elderly persons and for persons who have no opportunity for exposure to clear sunshine, a small amount of vitamin D is also desirable.

^eTo meet iron allowance, 1 large or 2 small servings of liver or other organ meats should be served each week.

Table XIV. ANOTHER LOW-COST FOOD PLAN (AT LOWER COST THAN PLAN IN TABLE XIII). WEEKLY QUANTITIES OF FOOD (AS PURCHASED) FOR 19 AGE, SEX, AND ACTIVITY GROUPS^a

<i>Family Members</i>	<i>Leafy, Green, and Yellow Vegetables</i>	<i>Citrus Fruit, Tomatoes</i>	<i>Potatoes, Sweet Potatoes</i>	<i>Other Vegetables and Fruit</i>	<i>Milk^b</i>	<i>Meat, Poultry, Fish</i>	<i>Eggs</i>	<i>Dry Beans and Peas, Nuts</i>	<i>Flour, Cereals^c</i>	<i>Fats and Oils^d</i>	<i>Sugar, Syrups, Preserves</i>
Children through 12 years:											
9-12 months	Lb. Oz. 1—8	Lb. Oz. 1—12	Lb. Oz. 0—8	Lb. Oz. 1—0	Qt. 6	Lb. Oz. 0—4	No. 5	Lb. Oz. 0—1	Lb. Oz. 0—10	Lb. Oz. 0—1	Lb. Oz. 0—1
1-3 years	1—8	1—4	1—8	0—8	5½	0—6 ^e	4	0—1	1—8	0—2	0—2
4-6 years	1—8	1—8	2—0	0—12	5½	0—8	3	0—4	2—4	0—6	0—4
7-9 years	1—12	1—8	3—0	0—12	5½	0—12	3	0—6	3—0	0—8	0—8
10-12 years	2—0	1—8	3—8	1—4	6	1—0	3	0—8	3—8	0—12	0—12
Girls:											
13-15 years	2—0	1—12	4—0	1—8	6½	1—0 ^e	4	0—8	3—12	0—12	0—12
16-20 years	2—0	1—12	3—8	1—8	4½	1—0 ^e	4	0—8	3—12	0—12	0—12
Boys:											
13-15 years	2—0	2—0	4—4	1—8	6½	1—4	4	0—12	4—12	1—2	0—14
16-20 years	2—4	2—0	5—8	1—8	6½	1—4	5	0—14	6—0	1—6	1—0
Women:											
Sedentary	2—0	1—8	3—0	1—4	5	1—0	4	0—4	3—0	0—8	0—8
Moderately active	2—0	1—8	3—8	1—8	4½	1—0	4	0—8	3—12	0—12	0—12
Very active	2—0	1—8	4—8	1—8	4½	1—0	4	0—12	4—12	1—0	0—14
Pregnant	2—12	2—0	3—0	1—8	7½	1—4 ^e	5	0—6	3—0	0—8	0—8
Nursing	3—0	3—12	4—4	1—8	10½	1—8 ^e	5	0—6	3—8	0—12	0—8
60 years or over	2—0	1—12	3—4	1—0	5	1—0	4	0—4	3—0	0—8	0—8
Men:											
Sedentary	2—0	1—8	3—8	1—8	4½	1—0	4	0—8	3—12	0—12	0—12
Physically active	2—0	1—8	4—8	1—8	4½	1—4	4	0—12	4—12	1—0	0—14
With heavy work	2—0	1—8	7—0	1—8	4½	1—4	5	1—0	7—12	1—14	1—4
60 years or over	2—0	1—12	4—0	1—4	5	1—0	4	0—6	3—12	0—10	0—10

^a From *Helping Families Plan Food Budgets*. Miscellaneous Publication No. 662, U. S. Department of Agriculture, Agricultural Research Administration, October 1952.

^b Or its equivalent in cheese, evaporated milk, or dry milk.

^c Count 1½ pounds of bread as 1 pound of flour. Use as much as possible in the form of whole-grain, enriched, or restored products.

^d For small children and pregnant and nursing women, cod liver oil or some other source of vitamin D is also needed. For elderly persons and for persons who have no opportunity for exposure to clear sunshine, a small amount of vitamin D is also desirable.

^e To meet iron allowance, 1 large or 2 small servings of liver or other organ meats should be served each week.

Table XIV (Continued). ANOTHER LOW-COST FOOD PLAN
SUGGESTIONS FOR KEEPING FOOD COSTS LOW^a

General. Check food costs constantly to take advantage of the best buys. Watch price specials and compare carefully from store to store.

Have a home garden, if possible—carefully planned around the family's needs.

Vegetables and fruits. Consider relative cost per serving of vegetables and fruits in different forms—fresh, frozen, canned, dried.

Use the cheaper grades of canned products. They are as nutritious as higher grades and satisfactory for many purposes.

Milk. Use forms of milk that are less expensive than fresh whole milk.

Evaporated milk for cereal, coffee, cooking.

Nonfat dry milk, skim milk, and buttermilk.

(Since these lack the fat and vitamin A value of whole milk, be sure to include in the diet at least the recommended quantities of other foods, especially those high in vitamin A value, such as leafy, green, and yellow vegetables.)

Eggs. Save by buying the lowest grade eggs that will serve the purpose—Grade A for poaching, frying, cooking in shells; Grade B for scrambled eggs and omelets, in cooking and baking; Grade C for cooking and baking.

Consider size as well as grade of eggs in relation to price. Allowing for differences in weight per dozen, small and medium-sized eggs may be a better buy than large eggs. Shell color also may affect price but not food value.

Meats, fish. Use the lower grades of meat, and the cheaper cuts. When comparing costs of different cuts, figure cost per serving—pieces with much bone may prove more expensive than more meaty cuts that sell at a higher price per pound.

Liver and some other organ or "variety" meats, such as heart and tongue, are highly nutritious. As a source of nutrients they are often less expensive than other meats, even when they cost more per pound.

Fresh fish is often inexpensive, especially near the source of supply.

Fats and oils. Compare prices of different fats and oils that serve the same purpose—some may cost much more than others.

Save drippings and fat trimmings for use in cooking.

Use cooked salad dressings in place of oil dressings.

^a From *Helping Families Plan Food Budgets*. Miscellaneous Publication No. 662, U. S. Department of Agriculture, Agricultural Research Administration, October 1952.

Table XV. SOME USEFUL EQUIVALENTS

1 meter (m.)	= 1000 millimeters (mm.)
1 meter	= 100 centimeters
1 meter	= 39.37 inches
1 centimeter (cm.)	= 0.394 inch
1 inch (in.)	= 2.54 centimeters
1 microgram ^a (mcgm.)	= 0.001 milligram
1 milligram (mg.)	= 1000 micrograms
1 gram (gm.)	= 1000 milligrams
1 gram	= 0.035 ounce
1 ounce (oz.)	= 28.35 grams
1 pound (lb.)	= 453.6 grams
1 pound	= 16 ounces
1 kilogram (kg.)	= 2.2 pounds
1 teaspoon (tsp.)	= 5 cubic milliliters (ml.)
1 tablespoon (tbsp.)	= 15 cubic milliliters
1 tablespoon	= 3 teaspoons
1 cup (c.)	= 16 tablespoons (level)
1 cup	= 12 tablespoons (fluid)
1 pint (pt.)	= 2 cups
1 quart (qt.)	= 4 cups
1 liter (l.)	= 1.06 quarts

^a Sometimes called gamma.

Table XVI. WORKING PLANS FOR THE CONSTRUCTION OF ADEQUATE DIETS

(a) For Preschool Children

Per Cent of Total Calories from Each Class of Food

<i>Calories</i>	<i>Milk^a</i>	<i>Cereals</i>	<i>Vegetables and Fruits</i>	<i>Eggs</i>	<i>Butter or Fortified Margarine</i>	<i>Sugar</i>
1,000	68	12-18	10-14	4-6	1-3	0-1
1,100	61	13-19	12-16	4-6	3-6	0-2
1,200	56	14-20	13-18	5-6	3-7	0-2
1,300	52	14-21	14-21	5-6 ^b	4-8	0-3
1,400	48	15-23	15-23	5-8 ^b	4-8	1-3
1,500	45	15-23	15-23	5-8 ^b	5-8.	1-4

^a Based on 1 quart milk.

^b May include some meat or fish or mild cheese.

(b) For Elementary School Children

Per Cent of Total Calories from Each Class of Food

<i>Calories</i>	<i>Milk^a</i>	<i>Cereals</i>	<i>Vegetables and Fruits</i>	<i>Meat, Fish, Poultry, Eggs, Cheese, Nuts</i>	<i>Fats</i>	<i>Sugar</i>
1,600	42	15-23	15-23	5-8	5-8	2-5
1,800	38	16-23	16-23	5-8	10-12	4-8
2,000	34	16-23	16-23	6-9	12-13	5-8
2,200	31	18-25	17-25	8-10	13-14	5-8
2,400	28	18-25	17-25	8-10	14-15	5-10
2,600	26	18-25	18-25	8-10	14-15	5-10

^a Based on 1 quart milk.

Table XVI (Continued). WORKING PLANS FOR THE CONSTRUCTION OF ADEQUATE DIETS

(c) For High School Boys and Girls

Per Cent of Total Calories from Each Class of Food

<i>Calories</i>	<i>Milk^a</i>	<i>Cereals</i>	<i>Vegetables and Fruits</i>	<i>Meat, Fish, Poultry, Eggs, Cheese, Nuts</i>	<i>Fats</i>	<i>Sugar</i>
2,000	34	16-23	16-23	6-9	12-13	5-8
2,100	33	17-24	16-24	7-10	13-14	5-8
2,200	31	18-25	17-25	8-10	13-14	5-8
2,300	29	18-25	17-25	8-10	13-14	5-9
2,400	28	18-25	17-25	8-10	14-15	5-10
2,500	27	18-25	18-25	8-10	14-15	5-10
2,600	26	18-25	18-25	8-10	14-15	5-10
2,800	24	18-25	18-25	8-10	16-18	8-10
3,000	23	18-25	18-25	8-10	16-18	8-10
3,200	21	18-25	18-25	8-10	16-18	8-10
3,400	20	18-25	18-25	9-11	17-19	8-10
3,600	19	18-25	18-25	9-11	17-20	8-10
3,800	18	19-27	18-25	9-11	17-20	9-11
4,000	17	20-30	18-25	9-11	17-20	10-12
4,500	15	20-30	18-25	10-12	17-20	10-12
5,000	14	20-30	18-25	10-12	17-20	10-12

^a Based on 1 quart milk.

(d) For Healthy Adults

Per Cent of Total Calories from Each Class of Food

<i>Calories</i>	<i>Milk^a</i>	<i>Cereals</i>	<i>Vegetables and Fruits</i>	<i>Meat, Fish, Poultry, Eggs, Cheese, Nuts</i>	<i>Fats</i>	<i>Sugar</i>
1,200 ^b	14 ^c	15-17	30-35	25-30	8-10	0-1
1,800	19	18-28	15-20	10-16	15-20	8-10
2,000	17	18-28	15-20	10-16	15-20	8-10
2,100	16	19-28	15-20	10-16	15-20	8-10
2,300	15	20-28	15-20	10-16	15-20	8-10
2,500	14	20-28	16-24	10-16	15-20	8-10
2,600	13	20-30	16-24	10-16	15-20	8-10
2,800	12	20-32	16-24	10-16	15-20	8-10
2,900	12	20-32	16-24	10-16	15-20	8-10
3,000	11	20-32	16-24	10-16	15-20	8-10
3,200	10	22-33	16-24	10-16	15-20	8-10
3,500	10	25-35	16-24	10-16	15-20	8-10
4,000	9	25-35	16-24	10-14	15-20	10-12
4,500	8	25-40	16-24	10-14	15-20	10-12
5,000	7	25-40	16-24	10-14	15-20	10-12

^a Based on 1 pint milk.

^b Reducing diet.

^c Based on 1 pint skim milk or buttermilk. Per cent will be higher if some whole milk is used.

Table XVI (Continued). WORKING PLANS FOR THE CONSTRUCTION OF ADEQUATE DIETS

(e) For Pregnancy and Lactation

Per Cent of Total Calories from Each Class of Food

<i>Calories</i>	<i>Milk</i>	<i>Cereals</i>	<i>Vegetables and Fruits</i>	<i>Meat, Fish, Poultry, Eggs, Cheese, Nuts</i>	<i>Fats</i>	<i>Sugar</i>
<i>Pregnancy</i> 2,500	27 ^a	15-20	15-20	10-16	12-18	8-10
<i>Lactation</i> 3,000	34 ^b	15-25	14-18	10-14	12-16	6-8

^a Based on 1 quart milk.

^b Based on 1½ quarts milk.

(f) For a Family of Two Adults and Three Young Children

Per Cent of Total Calories from Each Class of Food

<i>Level of Income</i>	<i>Milk</i>	<i>Cereals</i>	<i>Vegetables^a and Fruits</i>	<i>Meat, Fish, Poultry, Eggs, Cheese, Nuts</i>	<i>Fats</i>	<i>Sugar</i>
Low	20-27	33-38	12-14	7-10	12-14	5-10
Moderate	20-27	23-28	14-17	10-14	15-17	5-10
High	20-27	18-20	17-20	13-15	18-20	5-10

^a These percentages can be higher and those for cereals correspondingly lower when dried legumes are included.

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